UNIVERSITY
JAN

Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

JANUARY 1961

THE U.S.
ION PROPULSION PROGRAM

Advances in Electrostatic Propulsion . . A. T. Forrester & J. M. Teem
Manned Space Laboratory . . . . . Emanuel Schnitzer
New Standards for the Space Age . . . . . A. T. McPherson

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NOTE TO MISSILE PROJECT MANAGERS:
If you are not familiar with the latest developments in the use of Exploding Bridgewire techniques as a replacement for squibs, detonators, and other ordnance functions, write for Technical Bulletin 33.

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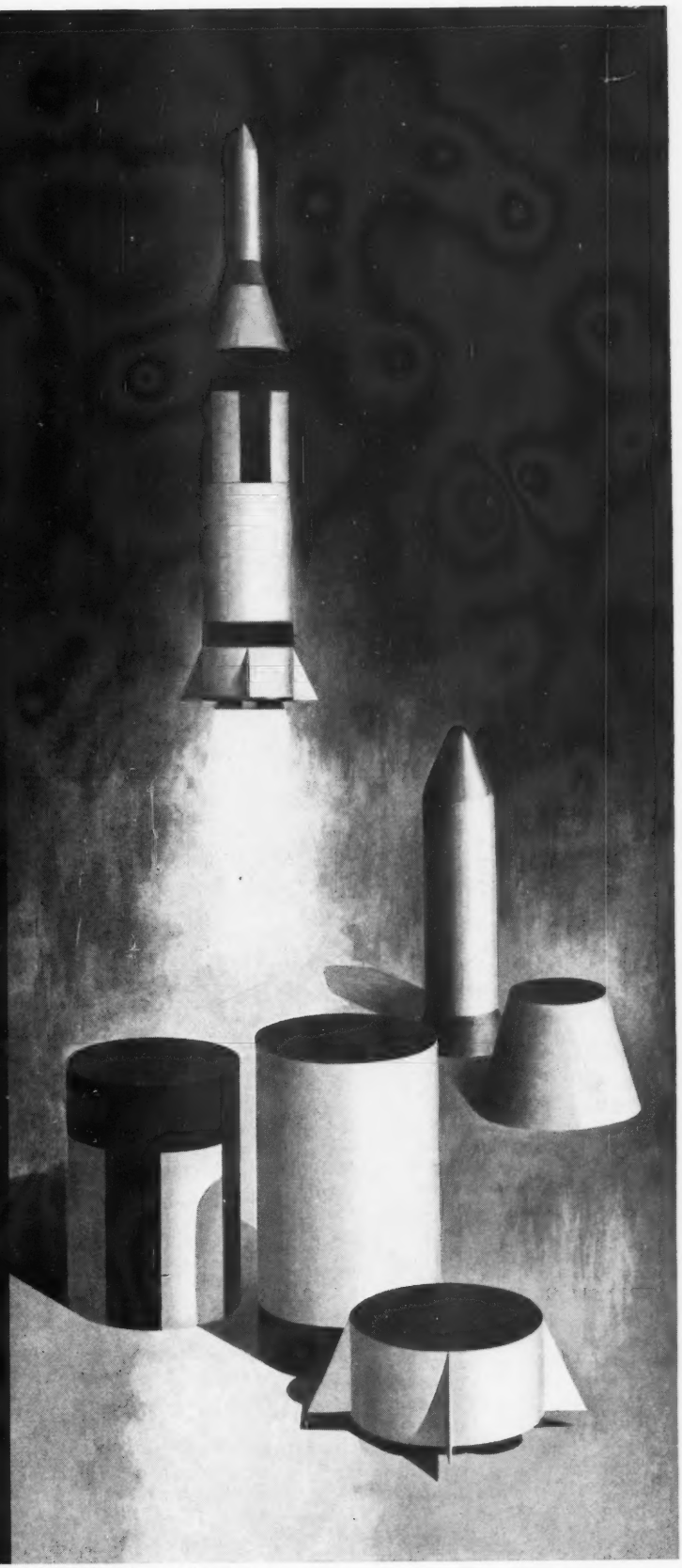


Engineers, scientists—investigate outstanding opportunities at Aerojet

LAUNCH
mailed to you regularly

Latest Experimental Meteorological Satellite on Course, Thanks to Bell Scientists — to Aid in Weather Forecasting

THE DAY of operational weather satellites is one step closer with the orbiting of the National Aeronautics and Space Administration's Tiros II.

An on-the-job, working satellite, the TV-equipped Tiros II will take pictures of cloud cover and transmit them to earth for limited, experimental use in forecasting weather.

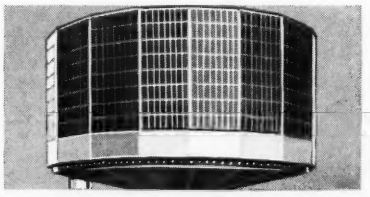
But despite its many instruments—TV cameras, tape recorders, solar cells and antennas—Tiros II would not be as useful if it were not in a nearly perfect circular orbit, made possible in large measure by the Bell Telephone Command Guidance System.

To provide accurate weather data, the satellite must be at an almost uniform distance from the earth at all times. Tiros II's orbit varies within extremely narrow limits as it constantly circles the earth.

Our Command Guidance System for the Tiros launching vehicle is a result of research and development by Bell Telephone Laboratories and production by Western Electric. This amazingly accurate system has scored many other successes in America's space program.

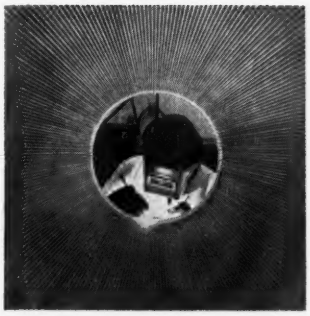
It has guided the successful Air Force Titan ICBM firings, and it helped make possible the first nose cone recoveries after flights of ICBM range. It also guided NASA's Tiros I and Echo I into their carefully planned orbits, and will be used in other forthcoming space probes and satellite launchings.

This Command Guidance System is one of a number of ways the Bell System is participating in the nation's space effort. The skills and knowledge called for in this pioneering activity are important assets in the country's defense.



More than 9000 solar cells—an invention of the Bell System—ring Tiros II and provide power for its instruments.

BELL TELEPHONE SYSTEM



COVER: Hollow stainless-steel tubes forming the thrust chamber of the Titan first-stage engine frame a welder working on the chamber at Aerojet's Liquid Rocket Plant in Sacramento in this striking photo. (ASTRO cover plaques, 11 by 12 in. are available from ARS Headquarters at $2.00 each.)

Astronautics

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Vol. 6 No. 1 January 1961

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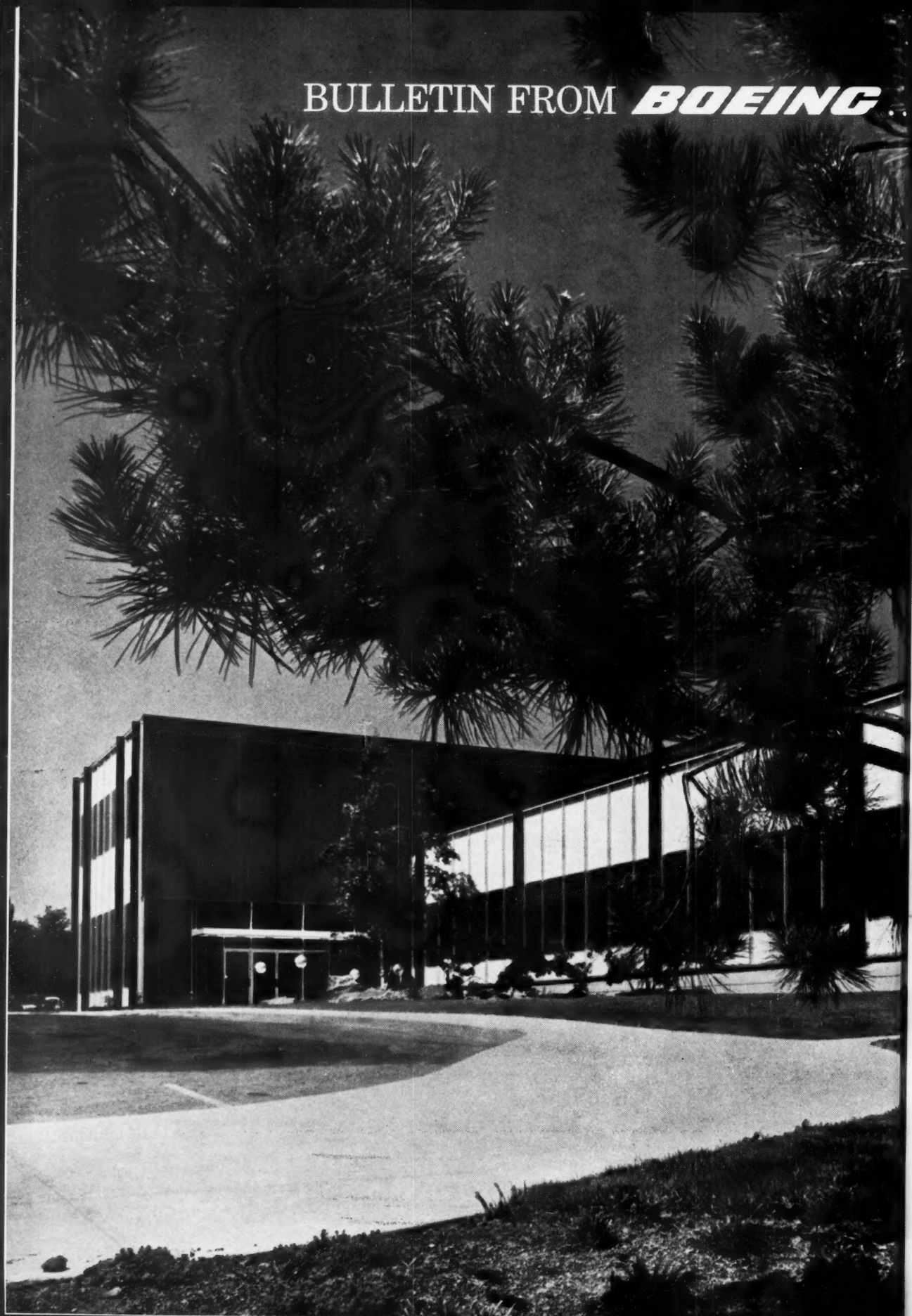
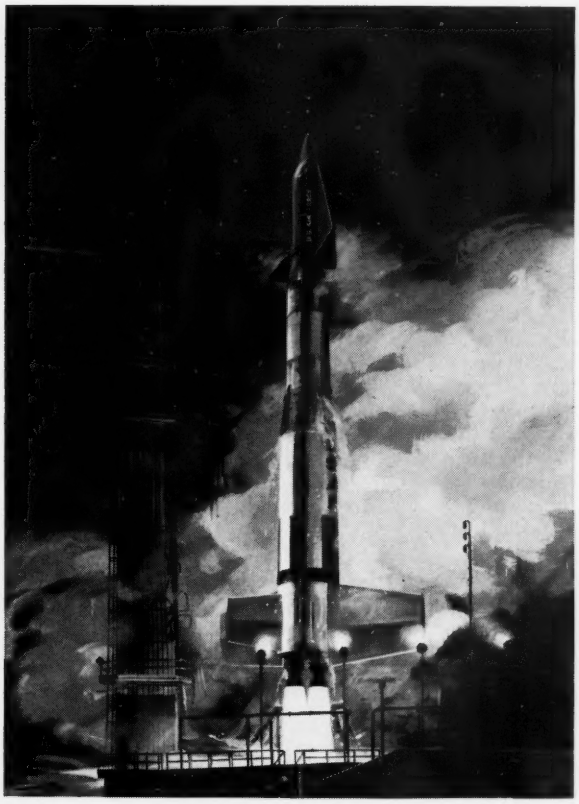
BULLETIN FROM BOEING

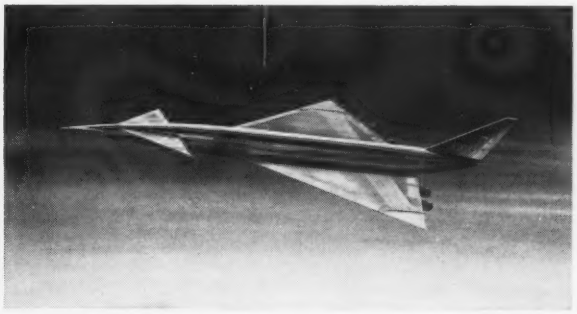


...WHERE CAPABILITY HAS MANY FACES

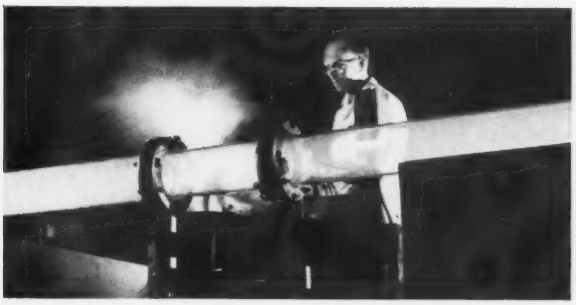
Expanding the frontiers of knowledge through basic research is the business of the Boeing Scientific Research Laboratories, left. Here Boeing scientists are at work in the fields of solid state physics, flight sciences, advanced mathematics, plasma physics and geo-astrophysics.



SPACE GLIDER. Artist's concept shows Dyna Soar manned space glider perched atop modified Titan ICBM for launching. In space, the glider and booster would separate, leaving Dyna Soar vehicle in piloted, near-orbital flight. Pilot could later glide to conventional landing at a selected base. Dyna Soar is being developed by the U. S. Air Force in cooperation with NASA, with Boeing as prime contractor for both the system and the glider.



FUTURE SKYLINER. Boeing, builder of famous 707, America's first jet airliner, has long been at work on next generation of aerial transports, which could look like the Boeing design pictured above. Supersonic jetliners, probably a decade away, could have speed in neighborhood of 2,000 miles an hour. Flight time, from Paris to New York, would be about two and a half hours!



SHOCK TUBE. Industry's most powerful shock tube, designed and built by Boeing Scientific Research Laboratories scientists, creates shock waves which begin at 300 times speed of sound, then collide in tube at "slowed" rate of 80 times speed of sound. Gas temperature within the tube reaches approximately one million degrees. Studies could be important in developing effective ion and plasma-propulsion systems for use in space.

BOEING

JET AIRCRAFT, MISSILES, HELICOPTERS, GAS-TURBINE ENGINES, WEAPON-SYSTEM MANAGEMENT, SPACE-FLIGHT VEHICLES AND SYSTEMS.

Astro notes

MAN IN SPACE

• It looked bad, especially in headlines. Project Mercury was jolted by two setbacks in November: Malfunction of the first flight test with a Redstone booster at Cape Canaveral, and failure of a Little Joe test of the capsule escape system at Wallops Island, Va. NASA said the Redstone malfunction would delay the MR-1 flight about four weeks, but insisted the 1961 goal of manned orbital flight remains intact. It scheduled a repeat of the Little Joe shot and pushed forward with preparations for MA-2, the second Atlas-boosted attempt with a McDonnell capsule.

• The MR-1 mishap resulted from a defect in the Redstone design which lay dormant for almost 60 firings. Ironically, NASA efforts to improve the tactical missile for manned flight probably brought the defect to light. A spurious electrical signal was generated in the Redstone when two plugs in its base failed to pull free simultaneously. Fast new relays added by NASA sensed the fleeting (20 millisec) voltage in the engine cutoff circuit and promptly terminated the flight.

• Then, NASA soon brought off the most successful public test to date in the man-in-space program. On Dec. 19, from Cape Canaveral, NASA launched a Mercury capsule, bearing instruments rather than a life-support system, in a perfect flight 235 miles down the Atlantic Missile Range with a newly tuned-up Redstone booster. Nothing succeeds like success, and this flight puts a lot of starch in the Project Mercury stance, discounting problems with Atlas boosters. According to Robert Gilruth, director of the Space Task Group for Mercury, "The next flight could include a chimpanzee." This flight might come by March.

• The Russians also seem to have had their troubles, though on a far more grandiose scale. Spacecraft III, another 5-ton space cabin, burned up with its two canine passengers, Pchelka and Mushka, when commanded to re-enter the atmosphere on its 18th orbit. The event suggested the Russians are still having orientation problems with their space vehicles. A similar trouble developed on Spacecraft I's flight last May 15.

• Brig. Gen. Don Flickinger, assistant for bioastronautics to Lt. Gen. Bernard Schriever, commander of ARDC, estimated the Russians are $3^1/_2$ to 5 yr ahead of the U.S. in space medicine research, despite the concerted effort of the AF in this field. He said it will take at least this long before the U.S. can duplicate the Soviet Spacecraft II, which successfully returned two dogs and a great variety of other biomedical specimens in August. Spacecraft II, he noted, showed excellent planning, optimum utilization of the biological payload, sophisticated recording and telemetry equipment, and a considerable mastery of life-support systems.

• A lively controversy seems developing over the seriousness of the radiation threat posed by solar storms. James Van Allen reported that Explorer VII was subjected to a flux of 10,000 protons per square centimeter per second during the sun storm of mid-November, the most lethal burst of solar particles during the satellite's 13-month lifetime.

• The AF, on the other hand, saw no acute danger in the storm of 20-mev protons. Its Discoverer XVII satellite was in space 50 hr during the peak of the storm and returned bacterial spores, algae, human eye and bone-joint tissue, and human gamma globulin, which were reported not harmed by the radiation dose, estimated at about 35 roentgens.

• According to George W. Crawford of the AF School of Aviation Medicine at Brooks AFB, San Antonio, Tex., who heads the biomedical-test-specimen phase of the Discoverer program, findings from Discoverer XVII indicate that "heavy shielding as protection for an astronaut against space radiation may not be necessary, at least for trips of less than 50 hr. Some of our specimens," he said, "were encased in different metals to test their effectiveness as shielding material, while other specimens were shielded only by a thin aluminum covering of the specimen capsule and by the thin shell of the satellite recovery vehicle. Analysis indicated that the specimens protected by the aluminum took a lower dose than those with lead shielding."

• These findings are in marked contrast to the results reported on the recent Nerv capsule, which carried mold neurospora through an approximately 20-min flight in the lower Van Allen belt. The neurospora were returned in a quiescent state referred to as "physiological death." Two of the three Nerv specimens were found contaminated, however, and it would appear that the as yet unexplained finding on the third will bear further experiments involving definitive controls.

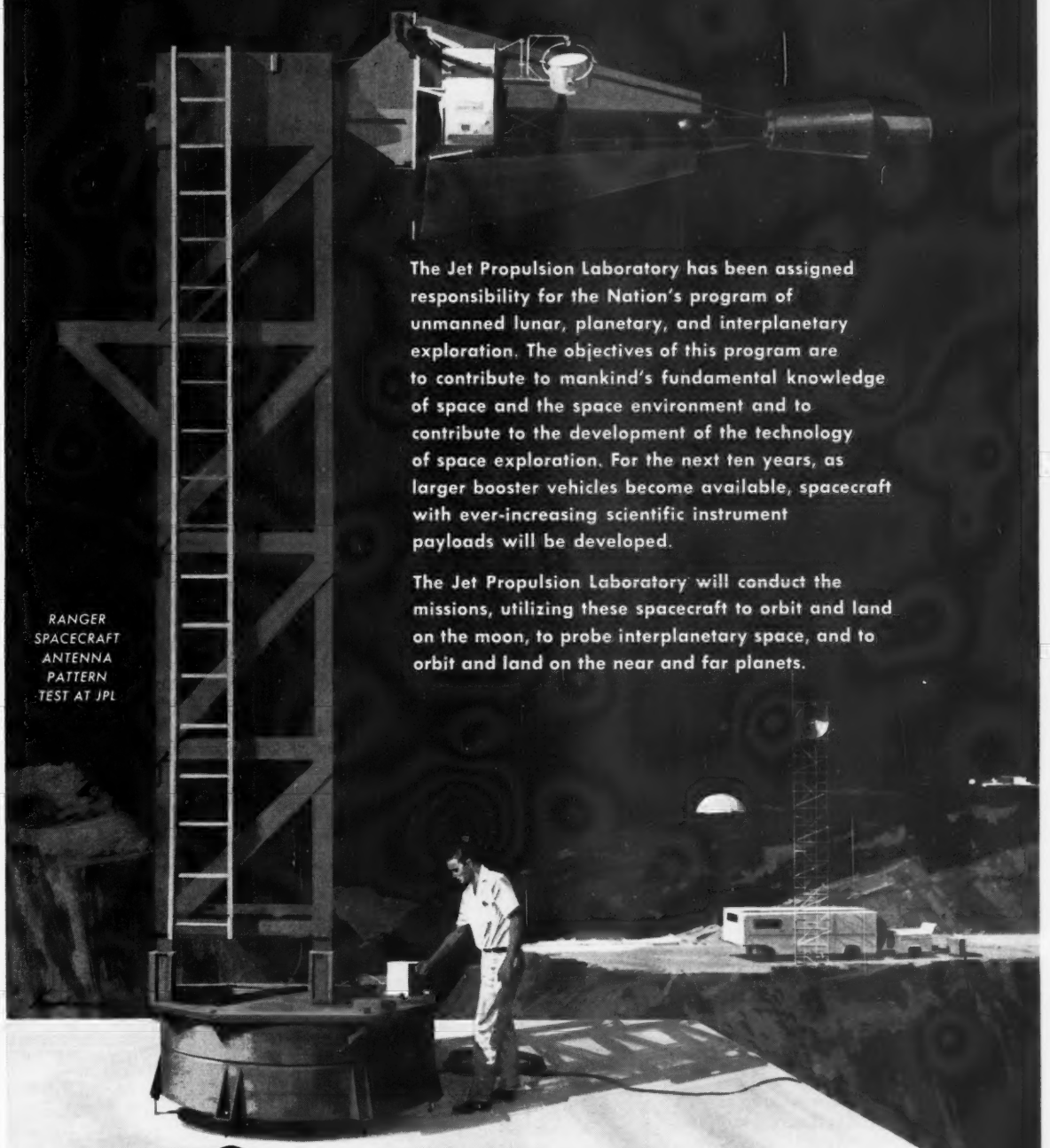
• The AF and Lockheed exhibited a mockup of 300-lb capsule designed to take a 50-lb chimpanzee into the heart of the inner Van Allen radiation belt during the Astronautical Exposition held in conjunction with the ARS Annual Meeting in Washington, D.C., last month. Part of a previously unannounced contract, work on the capsule fits into the AF's bid for more and larger programs in space.

• NASA-Langley has demonstrated the engineering principles for a reentry glider with a flexible wing and rigid leading edges that will maintain skin temperatures as low as 1500 F. The glider studies are part of NASA-Langley's concerted attack on the design of an orbiting manned laboratory, discussed by Manny Schnitzer on page 22. Advances in inflatable structures and materials for them, both by NASA-Langley and Goodyear Aircraft, coupled with progress in glider development, make the manned orbiting laboratory a development to watch closely. It pretty well pulls together the gamut of technology for manned orbital operations and the extension of these to lunar exploration via a ferry system.

• With the first flight testing of the X-15 powered by the Thiokol-Reaction Motors 50,000-lb-thrust XLR-99 engine now history, the long development program appears ready to reach a climax in its expected series of revolutionary hypersonic flights. It is possible that even more attention will be focused on pilot response in these flights than on the operation of the craft itself, and that there will be a spurt of development progress on manned re-entry vehicles based on evaluations of the first ballistic flights.

• The Triga nuclear reactor that General Dynamics will build for the new Armed Forces Radiobiology Research Institute at the National Naval Medical Center in Bethesda,

Pioneering in Space Research . . .



RANGER SPACECRAFT ANTENNA PATTERN TEST AT JPL

The Jet Propulsion Laboratory has been assigned responsibility for the Nation's program of unmanned lunar, planetary, and interplanetary exploration. The objectives of this program are to contribute to mankind's fundamental knowledge of space and the space environment and to contribute to the development of the technology of space exploration. For the next ten years, as larger booster vehicles become available, spacecraft with ever-increasing scientific instrument payloads will be developed.

The Jet Propulsion Laboratory will conduct the missions, utilizing these spacecraft to orbit and land on the moon, to probe interplanetary space, and to orbit and land on the near and far planets.

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JET PROPULSION LABORATORY

A Research Facility operated for the National Aeronautics and Space Administration

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Md., under a recently awarded contract for $2.4 million, will produce controlled momentary pulses of high-intensity neutron and gamma radiation for studying biological damage in terms of dose and exposure. Planned for completion late in 1961, this latest in GD's series of Triga reactors could become a key piece of equipment in the evolution of U.S. manned space vehicle programs.

• If the radiation doesn't get you, kidney stones will. That's the warning to astronauts issued by B. Dwight Culver of Aerojet-General. Prolonged weightlessness will release bone calcium into the kidney system to form the dangerous stones, Dr. Culver predicts. "The spaceman would return to earth in extremely poor physical condition. He would probably need immediate surgery to remove kidney stones and long rehabilitation to re-strengthen his wasted muscles." Be it ever so humble . . .

SATELLITES

• NASA's first attempt to orbit a Scout came to grief when the Castor second stage failed to ignite. The vehicle was to carry an 87-lb payload, including a 14-lb aluminized mylar balloon covered with polka dots and measuring 12 ft in diam. It was to be launched into a 38-deg orbit from Wallops Island, Va., for air density studies at a considerably lower altitude than that covered by the 100-ft Echo I satellite.

• NASA hopes to orbit a "Super Echo" in 1961 with twice its reflective cross section and a more rigid skin. The new sphere, measuring about 140 ft in diam, would probably consist of a layer of mylar sandwiched between two films of aluminum foil.

• Meantime, the AF announced that it, too, is looking into passive communication satellites, Wright Air Development Div. studying a novel lens-reflector satellite "100 times" more efficient than Echo. It would be covered with a large number of concave radio-frequency lenses mounted over spherical reflectors. The lenses would focus the radio energy on the reflector and re-focus the reflected energy into a beam encompassing the earth. The AF made a not very successful experiment with a passive sphere near the time of the Echo I launching; and in the future it plans to test a 10-ft model of the present design carried aloft in a high-altitude balloon.

• AF awarded Page Communications Engineers a contract to design and install the test range for the AF passive-lens satellite. The range system will record and process voice and teletype transmissions between Floyd, N.Y., and Trinidad, British West Indies.

• NASA orbited Tiros II, its second experimental weather satellite, but an optical failure in the wide-angle camera system sharply limited its contribution of panoramic cloud-cover data. The narrow-angle camera was working well, as was the infrared equipment. A third Tiros is planned next year, and the initial Nimbus shot is to come in the second quarter of 1962.

• The Weather Bureau is dissatisfied with NASA's deliberative pace in developing meteorological satellites, and has passed the word that it wants $133,400,000 in new funds in Fiscal 1962 to speed the development program and to buy eight more interim Tiros payloads and Thor-Delta boosters to realize an operational weather satellite capability at the earliest possible date.

• Representatives of Hughes Aircraft and Bell Telephone Laboratories announced the readiness of their companies to accept NASA's offer of rocket boosters on a cost-reimbursable basis to orbit experimental active communication relay satellites. Major questions still remain concerning the operating frequencies to be assigned the active repeaters. It is becoming increasingly apparent that the FCC is not going to assign the huge bandwidths initially requested for the relay satellites, and that the demands will have to be scaled down to more reasonable widths.

CUBAN MISHAP

• What can go wrong will go wrong, and usually in the most embarrassing way. This first law of rocketry made itself felt in November, when a Thor-Able-Star malfunctioned and fell on Cuba while attempting to place the Navy's Transit III-A navigation satellite in an orbit inclined 67.5 deg to the equator. The reliable Thor engine shut down 152 sec after liftoff, about 8 sec too soon. The safety officer detonated the first and second stages to prevent propellant from re-entering, and pieces of the rocket fell on a hillside near Holguin, at the eastern end of Cuba.

• Initial dispatches from Havana reported no injuries and no damage, but the story changed a few days later when university students demonstrated before the U.S. Embassy with six cows, one bearing a placard lamenting the loss of a "sister." Later the Cubans charged the U.S. with a "tremendous plot" against their sovereignty. Ludicrous or not, the incident is bound to complicate future high-latitude satellite launchings from Cape Canaveral. The State Department was never happy with the Cuban over-flights in the first place, and is now pressuring DOD to refrain from launching over any Latin American territory.

• Dog-leg trajectories can solve the over-flight problem; but the loss of payload can be very pronounced on sharp dog-legs. Other alternatives include construction of new and costly launch facilities on the West Coast, Hawaii, or aboard ship for a mobile launch capability. In a timely fashion, the Hawaii State Planning Office has just issued a brochure titled "Space Facility Capability" which sets forth capabilities and advantages of the Islands for space operations.

BUDGET FIRING LINE

• As the Kennedy Administration assembled and budget pressures mounted, the military services went all-out to assert their requirements for a variety of exotic space systems. The AF's shopping list called for manned space planes, communication satellites, and recallable ballistic missiles. The Navy's list called for most of the same items, plus the development of a sea-based satellite launching system and a "sea-based manned maneuverable interceptor spacecraft weapon system." At the Future Expectations in Space Flight panel at the ARS Annual Meeting, Capt. Robert F. Freitag of the Bureau of Naval Operations said the Navy looked to the development of a single-stage nuclear-powered manned spacecraft capable of hundreds of orbital missions.

• A couple of projects have made the funding stage. The AF announced the selection of Radio Corporation of America to proceed with the Project Saint satellite interceptor system using the Atlas-Agena B launch vehicle. Douglas Aircraft received a $139,248 study contract for a Space Logistics, Maintenance, and Rescue (Slomar) vehicle to deliver food, water, and personnel to manned satellites.

• Though the future of other projects was less apparent, the services

NOW, TIROS II

New Television and Infra-Red Observational Satellite

TIROS II—Improved experimental weather observer—follows TIROS I to provide man with new and more comprehensive views of earth's ever changing weather patterns from its vantage point some 400 miles in space. The new, more definitive pictures and data it gathers and returns to earth are providing a ground work for new giant strides in meteorology and long range weather forecasts.

Tiros II satellite, like Tiros I, was designed, developed and built by RCA's Astro-Electronics Division for the National Aeronautics and Space Administration. It includes all of the equipment of TIROS I—TV cameras, tape recorders, TV transmitters, command receivers, timing mechanisms, beacons and telemetry equipment—plus many new and improved devices. Chief among these are:

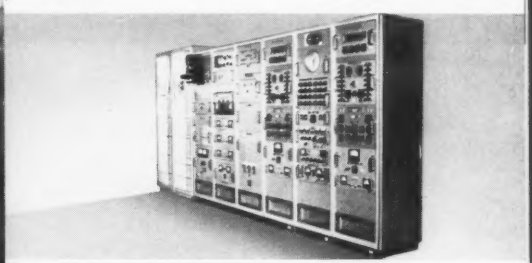
New scanning and non-scanning Infra-Red Sensing Devices—Developed by NASA to measure and record the heat radiation of the earth and its cloud cover adding new dimensions to existing weather data.

New Magnetic Orientation Device—a revolutionary advance to capitalize on the effects of the earth's magnetic field on TIROS II and maintain favorable orientation of the sensors over an extended period of time.

New noise suppressor circuits—to help eliminate extraneous noise from TV pictures TIROS II returns to earth.

New miniaturized RF Diplexer—to provide important savings in payload space and weight.

Improved horizon scanners and sun angle sensors—to give better orientation information for more efficient use of satellite photography and data.



Ground stations for TIROS II were designed and developed by RCA. This includes the primary stations at Fort Monmouth, N. J., at the Pacific Missile Range and the back-up stations at Princeton, N. J. and Cape Canaveral, Florida.

Many of these outstanding improvements were designed, developed, tested and incorporated in TIROS II within the short period of time since TIROS I was launched. It is an example of the kind of dynamic capability that is available to you at RCA's Space Center by simply contacting the Marketing Manager, RCA Astro-Electronics Division, Princeton, N. J.

If you are interested in participating in this challenging team effort, contact the Employment Manager, Astro-Electronics Division, Defense Electronic Products, Princeton, New Jersey.

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were driving hard to win top-level budget approval. The AF was particularly critical of NASA's assigned role in the area of manned space flight and super boosters.

RECOVERY SYSTEMS

• The AF Ballistic Missile Div. selected Martin and GE to build competitive recovery capsules for the Samos E-6 vehicle. Eastman Kodak will provide the photographic components for the E-6, and Aerospace Corp. will perform the initial system integration. Unlike Lockheed's E-5 Samos recovery capsule and the Discoverer, which must land in the Pacific, the new capsule will have high-precision reentry capability so that it may be returned to designated USAF bases on the U.S. mainland.

• Lockheed Missiles and Space Div. has completed the mockup of a life-support capsule capable of supporting a 50-lb chimpanzee for up to 14 days in orbit. The 350-lb system could be installed in the Samos E-5 recovery craft and launched into highly elliptical orbits traversing the Van Allen belts by the Atlas-Agena-B system. The capsule could carry 150 channels of telemetry (against seven for the Discoverer capsule carrying the rhesus monkey) plus a command television link. First flight of the recoverable chimp system could be achieved in two years, according to USAF biomedical experts.

• AF made it two in a row with Discoverers XVII and XVIII. Capt. Gene W. Jones made both air catches with his C-119 aerial retriever. Though the two Discoverer capsules were like those retrieved last summer, they remained in orbit 50 and 75 hr, respectively. The earlier capsules were limited to about 27 hr because of the supply of compressed nitrogen available for orientation; the larger Agena-B stage carries a considerably greater supply.

• All American Engineering Co. of Wilmington, Del., has developed a sea pickup system for rapid retrieval of Discoverer capsules that fall outside the aerial recovery corridor. Two frogmen parachute into the water and set up a pickup station aboard a 10-man life raft dropped near the floating capsule. A grappling hook attached to the capsule is placed atop a 20-ft pole in the center of the raft, and a C-119 engages the hook with its trapeze, pulling the capsule aboard. The system might prevent loss of capsules like Discoverer XV, which sank before surface ships arrived.

• Engineers of the Lockheed Missiles and Space Div. research laboratory propose the release of sodium vapor from re-entering space vehicles to form a visual-tracking "con trail." They suggest the sodium be sprayed at altitudes between 124 and 44 miles to show angle of descent and conformity to planned flight path, and at timed intervals to give velocity. Cesium would be used on cloudy days to give a good radar target. With 10 lb enough to lay a 100-mile track, they see major savings in weight for a sodium or cesium system over present bulky and heavy electronic equipment.

SPACE SCIENCE

• Explorer I and Albert Hibbs, head of the JPL Space Sciences Div., recently provided a moral for space researchers—Keep looking! A close examination of Explorer I data by Dr. Hibbs revealed a wide range in the micrometeorite counting rate as the satellite changed altitude. According to Hibbs, this effect could be caused only by cosmic dust moving in closed orbits around the earth, starting somewhere above 100-mile altitude and extending out several thousand miles.

• For Mars observers: Nicholas Pastore, writing in the November 11 issue of *Science,* reports an experiment leading to the observation of hues—typically blue, but also green and yellow—for two black figures, one of which is shadowed. Further experiments may give evidence for an interocular color effect.

• Recently reported discoveries from studies made with the 200-in. telescope at Mt. Palomar by scientists of the Mt. Wilson and Palomar Observatories, which are operated jointly by CalTech and Carnegie Institute: Evidence suggests that a certain distant galaxy may be 25 billion years old . . . A solar flare on a distant star produced a field of 34,000 gauss (largest sunspots produce about 4000 gauss)—the strongest magnetic field yet found in nature . . . New evidence shows that some stars have considerably different compositions than the majority of stars studied, such as our sun and many of its neighbors. One star has a hundred times the phosphorus as does the sun. Such deviant compositions will send the cosmologists back to theorizing about the basic structure of the universe and add another twist to the puzzle of how stars generate thermonuclear energy.

PROPULSION

• As reported at the ARS Annual Meeting, Rocketdyne hopes to complete a rating test of the 1,500,000-lb-thrust F-1 rocket engine early in in 1963. It could be tested in clusters of two engines by 1965, but clusters of 6 to 8 might not be ready for flight test until 1968–70, according to Rocketdyne engineers.

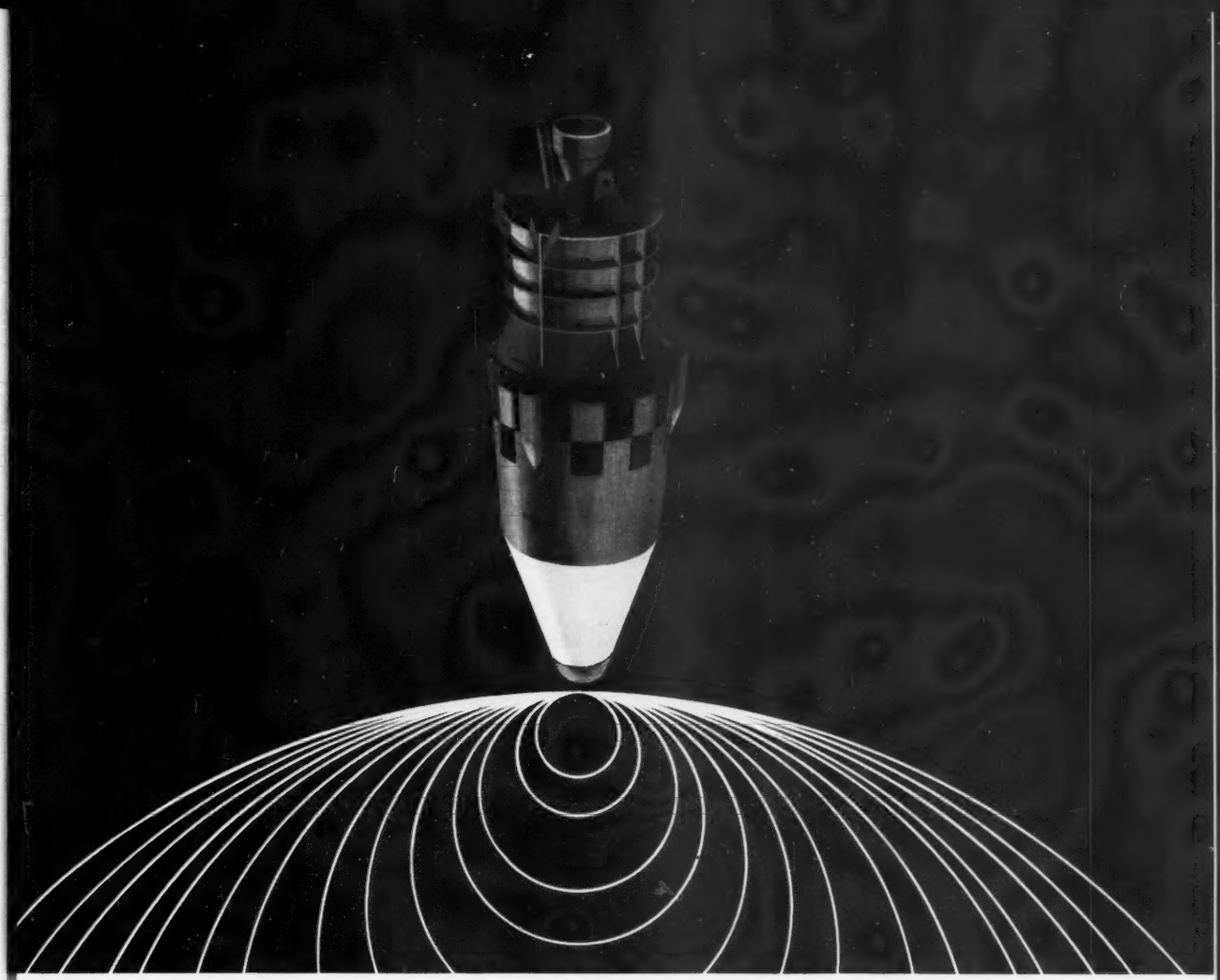
• New statistics on the F-1's mind-boggling dimensions were released at the ARS meeting in Washington. For example, its turbopump will weigh 2500 lb and will develop about 60,000 hp. Its gas generator will consume about 2 per cent of the total propellant in the tanks to move the remainder into the thrust chamber at a rate of almost three tons a second. The F-1's nozzle measures 11 ft in length and 9.5 ft in diam.

• Less than six months after receiving the go-ahead from NASA for work on the project, United Technology Corp. successfully static-fired a demonstration three-segment conical solid-propellant rocket motor of flight-test size. UTC Vice-President Barney Adelman said that perhaps the most important single factor in the firing was the good performance of the clevis-type joint used to join segments.

• NASA ordered about 60,000,000 lb of liquid hydrogen from Linde Co., a division of Union Carbide, for delivery through 1966 to NASA's West Coast contractors on the Centaur and Saturn programs. The contract, estimated at $31,000-000, calls for construction of a new Linde plant at Fontana, Calif., by mid-1962. Interim requirements will be supplied by Linde from an AF-owned plant at West Palm Beach, Fla.

• Aerojet-General Nucleonics expected high-flux runs of its fission-fragment process of producing hydrazine from ammonia to begin last month in the Livermore 2-megawatt pool reactor. If these tests confirm results in low-flux irradiation experiments, Nucleonics engineers estimate that it may be possible to produce hydrazine from ammonia at the amortized cost of about 25 cents a pound. Such a price would make hydrazine widely competitive as a propellant.

• Dow Chemical has awarded General Mills a contract to develop remotely operated equipment for as-



"MIDAS" REPORTS

through communications equipment by Philco

MIDAS II, the experimental "sentry in space," is the forerunner of a series of satellites that will detect the launching of ballistic missiles anywhere on earth and instantly relay the warning. Its entire communications system was designed and produced by Philco's Western Development Laboratories for the U.S. Air Force, as associate contractor with Lockheed.

This is another example of Philco's leadership in advanced electronics that is contributing to our national defense . . . in satellites, missiles, weapons systems, communications and data processing. For vast capacity, facilities and experience, look to the leader . . . look to Philco.

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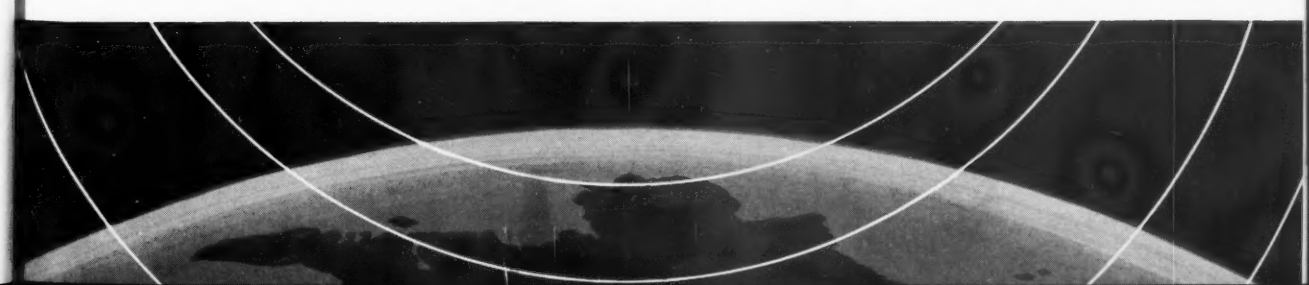


sembling and testing solid-propellant rocket motors. It will have a 200-lb hoisting and transporting capacity.

• News on the rapidly advancing fields of plasma and ion propulsion: The repetitively pulsed plasma accelerator being developed by GE's Missile and Space Vehicle Dept. has been fired continuously for $18^1/_2$ hr, producing about 1/10-lb thrust per pulse . . . Goodrich-High Voltage Astronautics Inc. showed models of the demonstration ion engine and electrostatic generator developed under sponsorship of ABMA and WADD; GHVA experiments are based on bombardment-type ion sources, and in particular the duoplasmatron arc source originally developed by M. Von Ardenne, and use mercury and argon as propellants . . . TRW's Tapco Group will conduct advanced research and development of their Vortex MHD Power Generator under contract to NASA . . . Northrop reports measuring continuous thrust on the order of 2 lb directly with their experimental MHD engine using nitrogen as propellant.

• Simulated-altitude tests (see page 28) at AEDC uncovered malfunctioning of the small solid retrorocket used to re-enter the Discoverer capsule. Repeated successes in the Discoverer program followed this engineering evaluation of the motor and other components.

• NASA was ready to send the Saturn booster into a new series of static tests late in November. The tests will be concerned chiefly with modifications to the rocket's tail section that were made as a consequence of the eight static firings ended last June. These changes involved further shrouds and shielding . . . Under an $85,000 NASA contract, Douglas Aircraft will conduct an eight-month study of Saturn C-2 system operations, from production to recovery after flight and reconditioning for further use . . . NASA-Marshall also opened negotiations with Packard Bell Electronics Corp.'s Technical Products Div. for the development of an automatic checkout system for the Saturn booster, and expected to conclude a contract by this month. Packard Bell was selected from among 16 companies submitting proposals. This equipment will put a Saturn vehicle through a simulated complete flight before the vehicle goes to the launch site at Cape Canaveral. The automatic checkout system may also be used for other rocket systems, and will have the capability of being expanded and modified to serve the upper Saturn stages.

• Moving ahead with the new plans to flight-test a nuclear rocket at the earliest possible date, NASA selected an industrial team for contract negotiations on the four-month study program for requirements of a national nuclear-rocket-engine development facility. The team consists of Ralph M. Parsons Co. in association with the Thiokol Chemical Corp., which represents the group called TALANT—Thiokol, Allison Div. of GM, Linde Co., a division of Union Carbide, and Nuclear Development Corp. of America.

MISSILES

• In a luncheon speech at the ARS Annual Meeting, Brig. Gen. Austin Betts, Director of the Advanced Research Projects Agency, flatly disputed Edward Teller's charge that an anti-ICBM missile cannot be developed. "A reasonably effective terminal defense system can be developed," he said.

• Nike-Zeus was flight-tested for the first time with its complete tactical guidance system on December 1. According to the Army, the test was a success, as was the performance of an improved technique for separating the missile's first and second stages.

• The chief problem facing Nike-Zeus development is that of decoy discrimination, said Gen. Betts. It now appears that this can be solved by interrelating several kinds of electromagnetic sensors, airborne as well as ground-based. The Pacific Range Electromagnetic Signature Study (Press) is designed to study this type of system. In conjunction with Army tests of the Nike-Zeus on Kwajalein, ARPA will install a modified BMEWS tracking radar of 2000-mile range (Tradex) on nearby Roi Namur. The Press equipment will obtain radar returns at many frequencies, as well as through infrared, ultraviolet, and optical sightings, all in real time with precise spatial relationships. All data will be fed into an on-site computer to provide "impressively better" information than ARPA has been able to obtain to date from its "DAMP" shipborne program at the Atlantic Missile Range.

• Initial installation of the Subroc fire control system will commence shortly on the SSN 593 Thresher nuclear submarine at Portsmouth. The weapon can be launched from a conventional torpedo tube; it breaks clear of the water and a Thiokol motor propels the warhead, a nuclear depth charge, up to 30 miles before dropping it in the vicinity of a target. Test launchings of the missile, under development by Goodyear for the Navy, are taking place without guidance or fire control at San Clemente Island off the Southern California coast.

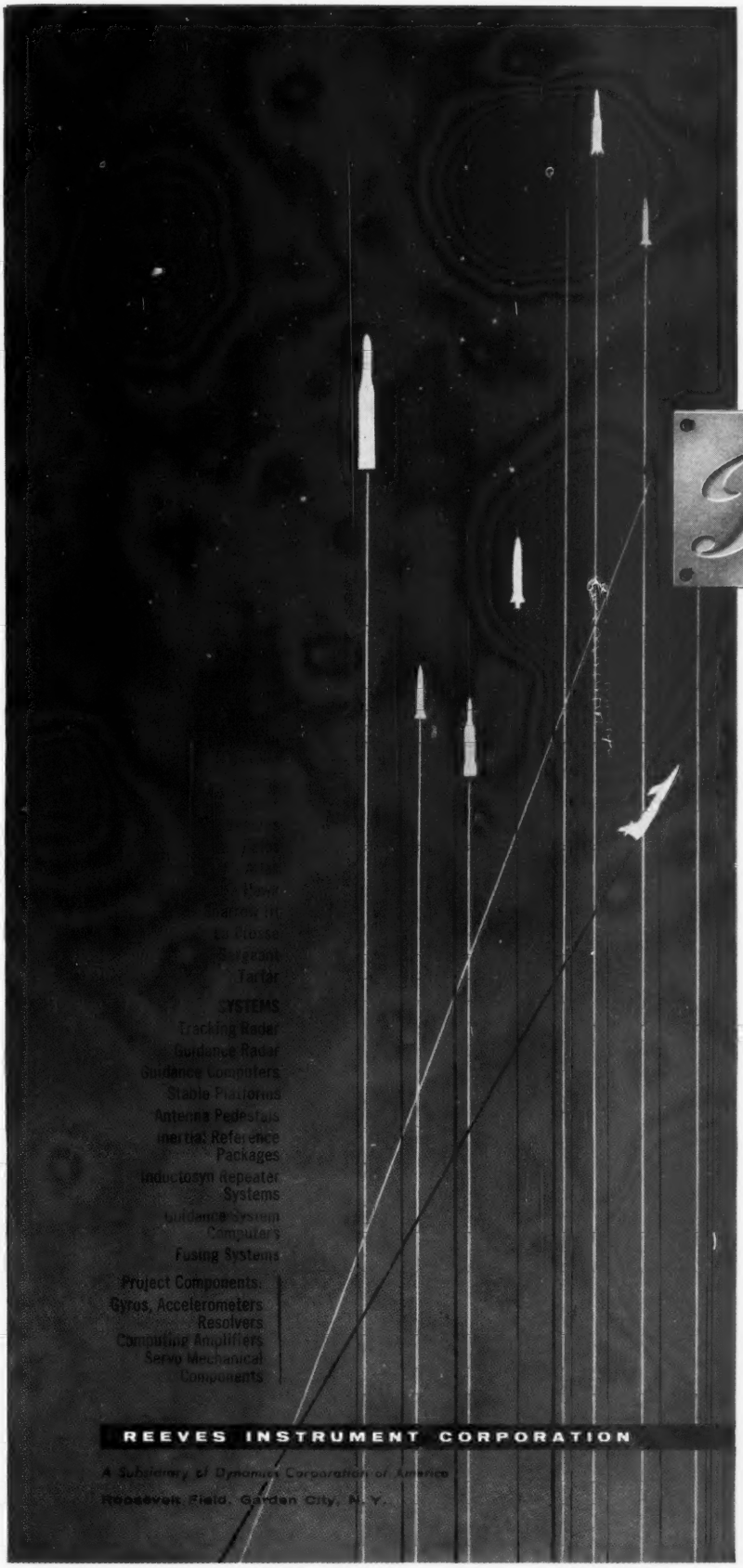
• The AF activated its first mobile Minuteman ICBM unit, the 4062nd Strategic Missile Wing, at Hill AFB, Ogden, Utah, in December. The Wing will receive two squadrons of railroad Minuteman missiles in 1962, the AF said. In the meantime, personnel assigned to the Wing will further develop the mobile-Minuteman program and start a training program for those assigned to the mobile squadrons.

• AF and Douglas have established a computer "watchdog" system to make sure the Skybolt air-launched ballistic missile is meeting all of its development deadlines. Called the "Program Evaluation Procedure," it involves programming 20,000 individual "events" in the Skybolt program on magnetic tape. These are analyzed against actual progress to disclose those activities which must be accelerated.

• Some recent contract awards: Martin-Orlando from the Army, $20.428 million for continued work on Pershing; Hughes Aircraft from the AF, $65 million for production of various versions of Falcon; Bendix Corp. from the Navy, $26 million for continued development and evaluation of Eagle; Raytheon from the Army, $2.25 million for further research and development on Hawk; Hughes Aircraft from Convair-Pomona, $300,000 to develop a guidance unit for the Mauler system; Food Machinery and Chemical Corp's Ordnance Div. from the Army, $4.95 million for design and development of the ground vehicle and launching pad for Mauler.

ARS TURNS OUT

• Some 2600 persons registered for the technical sessions and 2000 for the exhibits at the ARS 15th Annual Meeting held December 5–8 at the Shoreham Hotel. Daily luncheon attendance ran between 400 and 450, and the Honors Night Dinner drew a throng of almost 1500. The full story on the meeting will appear in next month's issue of *Astronautics*. ♦♦



a name-plate

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11RV59

For the record

The month's news in review

Nov. 3—NASA fires 90-lb Explorer VIII into orbit to investigate the ionosphere.

Nov. 4—Army says Courier satellite launched Oct. 4 stopped sending messages on Oct. 23, but radio tracking beacon is still functioning.

Nov. 6—Japanese Space Development Council Report advises its Government to initiate soon basic studies aimed at launching an earth satellite.

Nov. 8—Mercury capsule fails to separate from its Little Joe booster during stress test.

—AF attempt to hurl Blue Scout radiation-study payload 24,500 miles up is balked when second stage burns out too soon.

Nov. 10—Navy successfully launches advanced Polaris (A-2) on a record 1600-mile flight.

—DOD integrates Spasur and Spacetrack systems under control of Continental Air Defense Command.

Nov. 12—AF launches 2100-lb satellite-rocket Discoverer XVII into polar orbit. Capsule carries artificially-grown human cells and plants, expected to shed new light on radiation damage.

Nov. 13—Navy announces it is developing techniques for low-cost satellite launchings from an airplane, ship, barge, or from under water.

Nov. 14—DOD says NASA, AF, Army, and Navy are jointly building a geodetic satellite to map the earth accurately.

—AF C-119 snares Discoverer XVII capsule in mid-air.

—AF says Discoverer XIII satellite body burned upon re-entry into the earth's atmosphere.

—AF reports having sent printed messages and weather maps up to 900 miles by bouncing radio signals off meteor trails.

Nov. 15—AF recovers data capsule of Atlas fired 5000 miles.

—AF Mace-B is successfully flight-tested 1000 miles.

—AF flight tests X-15 equipped with new XLR-99 engine.

Nov. 17—Last flight test in Polaris A-1 1300-mile series fails in otherwise successful test program.

—U.S. proposes upper-atmosphere probes from Woomera Rocket Range, using British-built Skylark rockets.

Nov. 21—Mercury rocket escape tower breaks loose from capsule, leaving Redstone booster on pad, as third capsule test fails.

—AF 500-lb capsule launched to 32-mile altitude is returned safely to earth via Ballute system of drag ballon and parachute.

—NASA reveals that development work has begun on an infrared homing device to navigate U.S. Mars and Venus probes planned for 1962.

—Soviet Union releases detailed map of far side of moon based on information from Lunik.

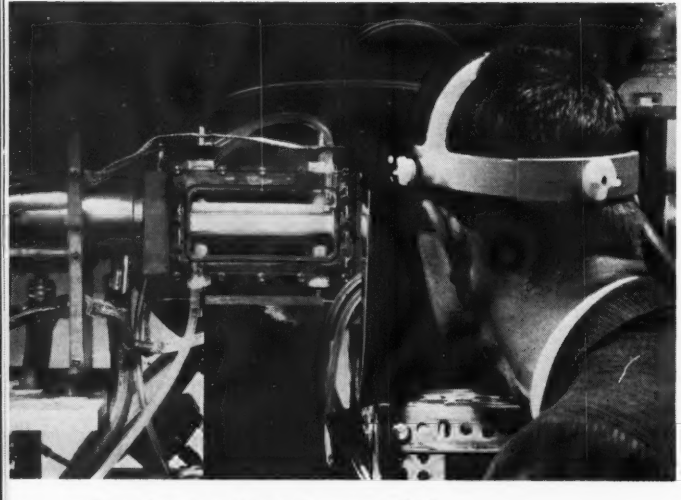
Nov. 22—NSF selects Table Mountain, near Boulder, Colo., as site of a National Center for Atmospheric Research.

—U.S. and India announce joint program of some 40 high-altitude balloon flights over India starting Dec.

Nov. 23—NASA launches Tiros II into orbit.

Nov. 25—NASA scientists speed up spin of Tiros II via ground radio command.

Nov. 28—Belgium, Denmark, France, W. Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, and the U.K., with Spain sitting in, meet to formulate foundation for a European space organization.



Crossed-Field Acceleration Hypersonic Wind Tunnel

Allis-Chalmers and MHG Research, Inc., have developed a long-running-time tunnel to simulate conditions encountered by ballistic missiles and space vehicles. The prototype model, shown here, has horizontal electrodes on either side of the plasma stream, with one of the two circular magnetic coils in the background. In tests lasting up to 20 min, the energy of the plasma stream has been increased by 60 per cent with little or no increase in contamination.

ELECTRICITY FROM NUCLEAR HEAT

Development of a plasma-thermocouple to convert nuclear reactor heat directly to usable amounts of electrical power is a notable achievement in basic scientific research at Los Alamos.

For employment write to:
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Division 61-3

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

Original painting by Oli Sihvonen, Taos, N. M.

The most proven large ballistic missiles, the Atlas (left) and Redstone (right), will launch America's Astronauts. Main-stage engines of both are by Rocketdyne.

AMERICA'S ASTRONAUTS WILL BE LAUNCHED INTO SPACE BY ROCKETDYNE ENGINES

America's man-in-space programs demand the ultimate in reliability. There is no room for error—that is why America's most experienced rocket engines have been chosen for the job.

And this means engines built by Rocketdyne.

A Redstone engine, whose performance over a decade of development includes 62 consecutive successful flights, will loft the first manned space craft high over the Atlantic in an exploratory ballistic arc.

Then an Atlas system of five engines, proven in more than 60 development and operational flights, will send a man soaring upward more than 100 miles to circle earth for four hours during man's first orbital flight in space.

To that dramatic moment, Redstone and Atlas will carry the heritage of more than 18,500 large engine tests at Rocketdyne's Propulsion Field Laboratory.

At every level of operation—from engineering to manufacturing to cost control—Rocketdyne has pioneered new concepts. Advanced management programs, combined with vast experience and the foremost high-thrust test facilities in the nation, give Rocketdyne the capability today to meet the challenges of tomorrow.

Rocketdyne engines have launched more than 250 missiles, satellites, and space probes.

FIRST WITH POWER FOR OUTER SPACE

ROCKETDYNE

DIVISION OF NORTH AMERICAN AVIATION

Canoga Park, California; Neosho, Missouri; McGregor, Texas

Mail bag

En Garde, Stoiko, and Dorsey!

Dear Sir:

I found in reading your July issue article "Rocket Catapult Facts and Fables" by Michael Stoiko and John W. Dorsey that it in itself was a fable surrounded by distorted facts.

Distorted facts like the suggestion that a British-designed steam-catapult water brake, shortened to the limit for aircraft carrier space and short cycle time requirements, be scaled up to an undesirable capacity is a distortion due to its imprudent selection for an entirely different purpose. Poo-pooing catapults based on facts like these is not only misleading to your readers but may give reassurance to Russian engineers if they happen to have a practical missile launcher.

First, let us review how the fable was built that concluded that catapults for extremely large rockets were not desirable.

1. Select a missile weighing 1,000,000 lb.
2. Select an acceleration of 10 "g" for the catapult.
3. Apply this 10,000,000-lb force on the missile until the missile is traveling at the amazing ground level velocity of 1000 fps.
4. Select an efficiency of 75 per cent for the catapult.
5. Determine the resultant energy to be 20,000,000,000 ft-lb using a 1500-ft run.
6. Show how big and impossible some catapults as presently designed for horizontal use would be if scaled up to obtain the energy that (a) is concluded to be undesirable because the end speed is too fast if (b) the same or similar thrust to the rocket is imparted to get a similar trajectory (meaning at this point up) until we over heat the rocket by going too fast too low.

Allow me to spin a fable with a different ending. The other fable was too sad for me.

1. Select a missile weighing 1,000,000 lb.
2. Select an average acceleration of 5 "g" for the catapult.
3. Select a hydraulic, span-type, self-arresting catapult.
4. Apply the 5,000,000-lb force on the rocket for 1000 ft to obtain an end speed of 550 fps.
5. Determine the resultant energy to be 6,700,000,000 ft-lb.
6. Suggest that one of the catapult designs to be developed for this energy level be as follows:

(A) Four piston-cylinder combinations with crosshead and multiple sheaves for two parallel reaved cable systems with these dimensions: Piston diam, 200 in.; stroke, 50 ft; reaving ratio 20 ft of rocket stroke for 1 ft of piston (10 pairs of sheaves); cylinder pressure of 2000 psig.

If you have looked at the 200-in. piston diameter and have judged it too big then let us use 10 individual piston cylinder combinations 56 in. in diam tied together to produce the same result.

(B) The individual piston terminal velocities are $27^1/_2$ fps and can, as some similar catapults have been, be designed self-arresting.

(C) The 2000 psig can be obtained from many sources, from "fuel-gas generators" to "compressed air."

Note: This design is not free from difficulties, but the design is not impossible.

7. What can we do with the energy we have just saved? We can carry approximately 10,000 lb of extra cargo and/or fuel as we proceed at a lower acceleration up to the 500,000 to 600,000-ft altitude where temperature increase is a straight-line, slowly increasing, temperature function relatively independent of rocket velocity.

8. The happy ending: A rocket propelled under controlled or metered thrust conditions with a bigger payload, such as more people or equipment, perhaps even a small catapult and arresting gear for the moon.

I have had the pleasure of being the Development Engineer for the projects called Skycatch and Fishhook which caught test missiles launched by a launching system. If we had listened to people who said that these projects couldn't or shouldn't be done, the U.S. wouldn't have the protection of an operational missile at this time.

FORREST E. KNECHT, Development Engr.
Experimental Div., Engineering Dept.
NAEF, NAMC
Phila. 12, Pa.

Guidance State of the Art

Dear Sir:

It is with great interest that I read the November 1960 issue of *Astronautics* and, in particular James S. Farrior's paper on the State of the Art of Guidance and Navigation. The article mentioned is informative, enjoyable reading as a whole, and covers a rather broad variety of topics consistent with military security. It is with astonishment that I noticed, however, the complete absence of any reference to the Arma Div. of American Bosch Arma Corp., while quite a prominent place and emphasis was given to certainly meritorious, but by no means outstanding, achievements.

As you know, the Arma Div. is the first and only company which developed a fully inertial guidance system and associated missile-borne digital computer used on an operational ICBM. In fact, this achievement made history in the missile art of the Free World, and the Arma Div. is particularly proud of the fact that the first inertially guided U.S. ICBM flew with an Arma guidance system. I should mention that this completely static, transistorized guidance equipment contains unique features and is the result of major breakthroughs without which the state of the art could not have been advanced to the degree actually achieved in an operational status. Military classification prevents me from disclosing precise design and performance data.

Within permissible limits, I may say, however, that the performance of the Arma guidance system, as demonstrated repeatedly through successive firings of the Atlas missile, exceeded substantially both the specifications and the most optimistic expectations of the Air Force.

With these considerations in mind, it seems to me that Mr. Farrior's terse reference to the name of the airframe manufacturer (Convair), while leaving Arma's name and significant achievement out entirely, is one-sided and puts the emphasis upon one particular phase of the Atlas project which is certainly not the most essential contribution to the outstanding success achieved. Apparently, Mr. Farrior failed to recognize that in the present state of the art, the major, or possibly the only radically new, approach to any ICBM guidance scheme which has reached an operational status is the Arma system applied to the Atlas.

PAUL H. SAVET, Staff Scientist
Arma Div., American Bosch Arma Corp.

Editor: One of the perils of a state-of-the-art review. We appreciate Mr. Savet's comments.

Pfaudler Introduces Nucerite Coatings

A new ceramic coating material, called Nucerite, has been introduced by the Pfaudler Div. of Pfaudler Permutite Inc., Rochester, N.Y. Involving a silicious matrix, the material is tough, hard, and temperature resistant, remaining stable at up to 2500 F for short periods and up to 1800 F for long periods. It appears to have wide applications in high-temperature heat exchangers involving corrosive working fluids and in similar applications. Pfaudler is keeping the material under wraps, but is negotiating with several major companies to coat equipment for space vehicles with Nucerite. Nucerite coatings can be formed to close tolerances.

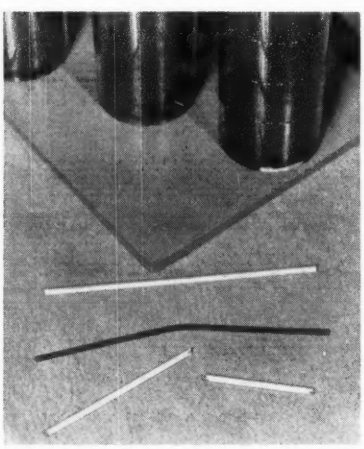
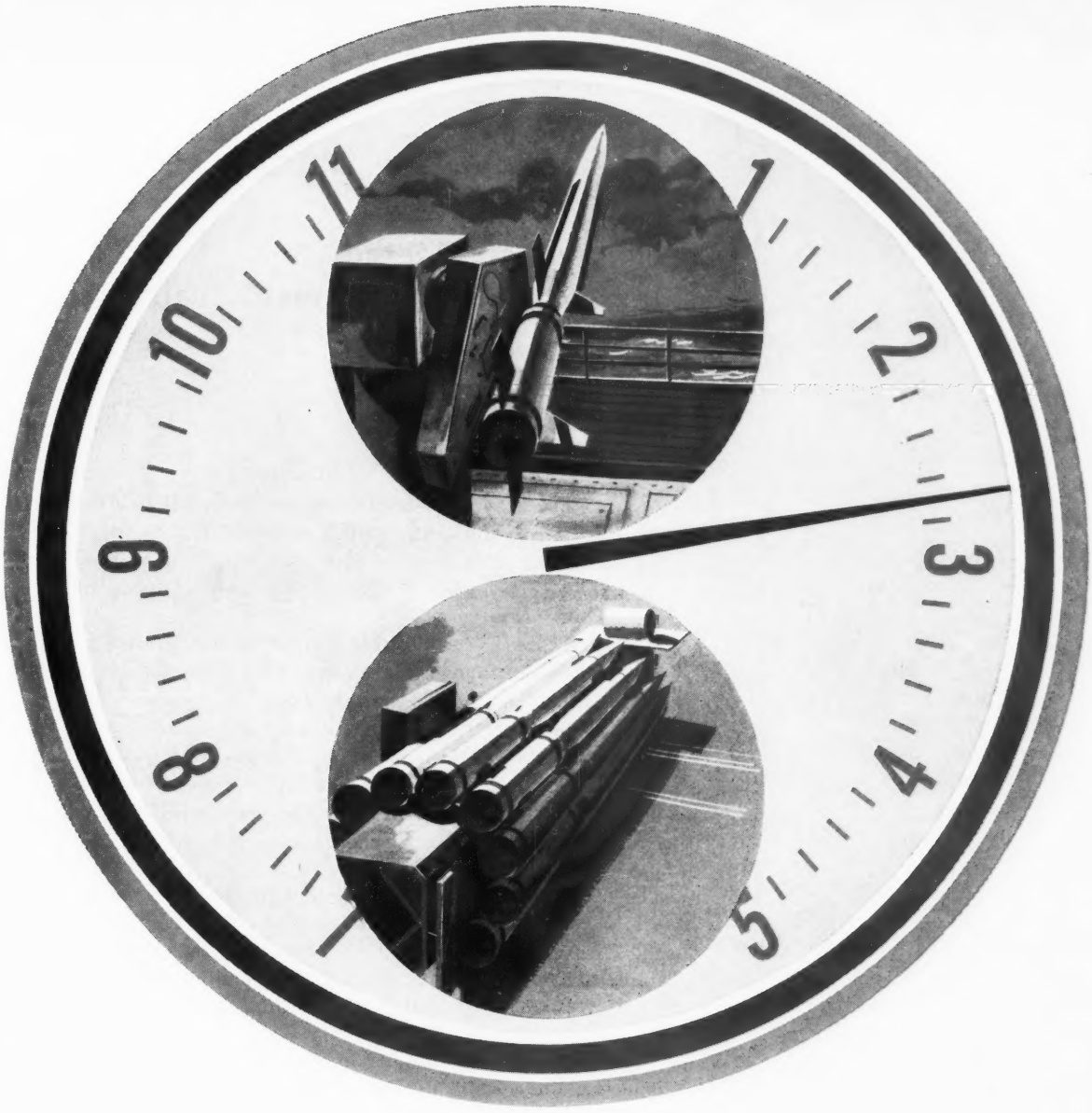


Photo shows a Nucerite rod (top) that took 85,000-psi stress without deforming; below it, mild steel deformed at same stress, glass that broke at 25,000 psi. In background, test weights, which depended from wire handles.



FROM REST TO READY....**LESS THAN A MINUTE**

■ Below deck, missiles are stored naked, stripped of stubby wings. But in less than 60 seconds they're assembled, loaded and fired, thanks to automation. ■ Take this concept – develop the idea into today's mighty missile systems. Vitro did: its technical staff helped the Bureau of Naval Weapons design fully-automated missile handling and launching systems – ones now used aboard frigates, cruisers and carriers armed with fast, ship-launched Terrier and Talos missiles. ■ Vitro scientists and engineers went right to work during basic ship design – providing space needed for automatic storage and handling. Beyond this, Vitro takes ideas and develops actual systems for feasibility testing.

Vitro

VITRO LABORATORIES/Division of Vitro Corporation of America/SILVER SPRING, MD. • WEST ORANGE, N.J. • EGLIN AFB, FLA.
SCIENTISTS AND ENGINEERS: JOIN THIS TEAM

One of a series.

Why we eliminated the earth's magnetic field... almost

In an isolated laboratory in southwestern Ohio, GM Research scientists have reduced the earth's magnetic field to one ten-thousandth of its usual strength. This is about as weak as the interplanetary field detected by the Pioneer V solar satellite.

Why neutralize the earth's field? To perform with precision one of the more fundamental experiments in magnetism — measuring the Einstein-DeHaas effect. The measurement is simple in concept, experimentally difficult because of the tiny forces involved. It is made by suspending a ferromagnetic rod in a nearly field-free environment . . . magnetizing the rod . . . then measuring the effect (how much the rod rotates) when this known magnetization is reversed.

The beauty of the experiment is that the resulting values can be related directly to the motions of electrons in the rod. The values indicate the large portion of magnetization due to the *spin* of electrons . . . and the slight, but theoretically important, remaining portion due to *orbital* motion of electrons.

These measured values are helping scientists form a better understanding of the perplexing phenomenon — ferromagnetism. Currently being pursued in cooperation with the Charles F. Kettering Foundation, this long-standing project is one of the ventures in basic research of the General Motors Research Laboratories.

General Motors Research Laboratories

Warren, Michigan

Gyromagnetic Ratios

	a	***b***
Iron	*1.92*	*1.90*
Cobalt	*1.85*	*1.83*
Nickel	*1.84*	*1.83*
Supermalloy	*1.91*	*1.91*

Comparison of (a) gyromagnetic ratios measured in the new Kettering Magnetic Laboratory with (b) corresponding ferromagnetic resonance measurements. These ratios would equal 2 if magnetization were due only to electron spin, or 1 if due only to orbital electron motion.

System of Helmholtz coils used to neutralize earth's magnetic field.

Headquarters Building for ARS?

For a number of years, the fact has been recognized that a permanent, Society-owned headquarters building would enable the American Rocket Society to pursue more effectively its objectives on behalf of its 17,000 members. Such a building would have the stabilizing effect of an endowment on our rather kaleidoscopic financial situation—a situation that is directly related to the fact that in order to provide necessary services for our fast-growing field, we consume all the income received from advertising, membership fees, and exhibits practically as soon as we get it.

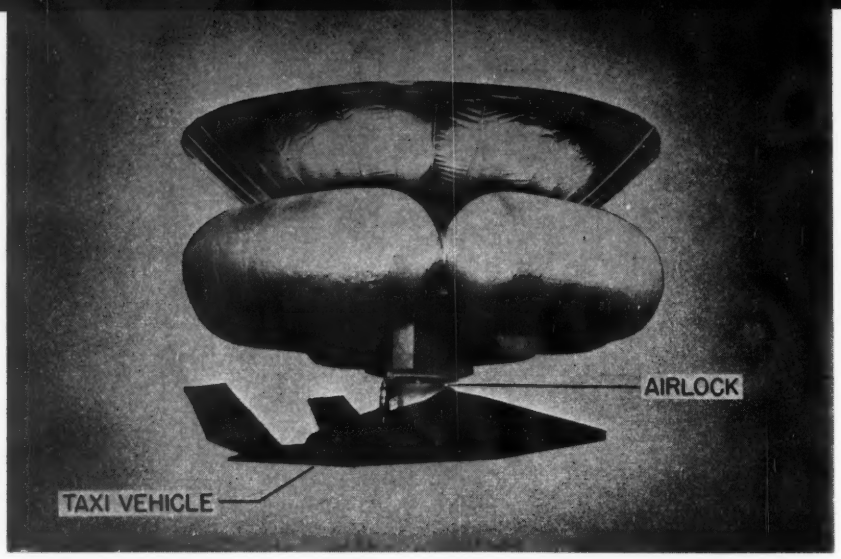
A building would enable us to save on rent and provide growth space. It would also call symbolic attention to the fact that there *is* an astronautics field in the U.S. and a Society which is energetically seeking to serve it. To a world which equates progress in science to progress in space—rightly or wrongly—such symbolism has high value.

The question of a building has been under intensive study for the last year. For a modest fee, a professional fund-raising organization (the same one that did such an effective job in raising funds for the United Engineering Center just being completed in New York City) has conducted a preliminary survey, reported conclusions, and made recommendations for further actions. Although the model plan under study assumed a building costing $3,000,000, located in New York City, and containing a library and museum, a final decision on whether or not to go ahead with the plan, where the building would be located, and what features the building would have, has not been made.

Over the next three months, more information will be collected, and the matter will again be reviewed by the Board of Directors in April. The Development Committee is currently under the able chairmanship of ARS Director J. R. Dempsey, Vice-President, Convair, and General Manager, Convair-Astronautics.

The membership will be kept posted continually on the considerations and actions of the Committee regarding this project—a project of importance to the entire astronautics field.

Harold W. Ritchey
President, American Rocket Society



Models depict a Dyna-soar-like earth-to-space taxi rendezvousing with an automatically erected toroidal laboratory to deliver the crew.

Designing a self-erecting manned space lab

The automatically erecting spacecraft may prove a major link in manned exploration of the moon and planets and observation and research in space

By Emanuel Schnitzer

NASA LANGLEY RESEARCH CENTER
LANGLEY FIELD, VA.

Emanuel Schnitzer is an astronautical research engineer of the NASA-Langley staff. After receiving a B.S. in mechanical engineering from the Univ. of Illinois in 1943, he did servomechanism research and instrument development at Sperry Gyroscope, Armour Research, and NACA-Langley Laboratory, and then cyclotron design for the Univ. of Chicago. In 1949, he returned to NACA and conducted research which culminated in the bandpass shock absorber. For the past two years, he has engaged in research on erectable satellite structures, such as the Echo communications sphere, and configurations applicable to space stations and laboratories.

AMONG the long-range objectives of space flight are manned exploration of the moon and planets and the provision of manned earth satellites for scientific observation and research. The next major step toward accomplishing these objectives points to the establishment of a manned orbiting space laboratory. This laboratory should be capable of supporting life in space from several weeks to a year, depending on whether lunar or interplanetary trips are to be simulated.

The purposes of this manned space laboratory might be outlined as follows:

1. To study man's ability to adapt to
   (a) long periods of reduced gravity
   (b) radiation levels encountered in space
   (c) operate in an artificial life-support system
2. To study materials and structures, and to prove out stabilization systems and auxiliary powerplants in a true space environment before committing them to use at long distances from the earth.
3. To study means of communication, orbit control, rendezvous problems, and techniques of astronomical observation and earth surveillance, where man's immediate judgment in selection, control, and interpretation of results is required.

The whole concept of the space laboratory, then, is seen to be predicated on providing the fundamental background for more advanced space missions.

Accordingly, NASA has focused a part of its research effort on

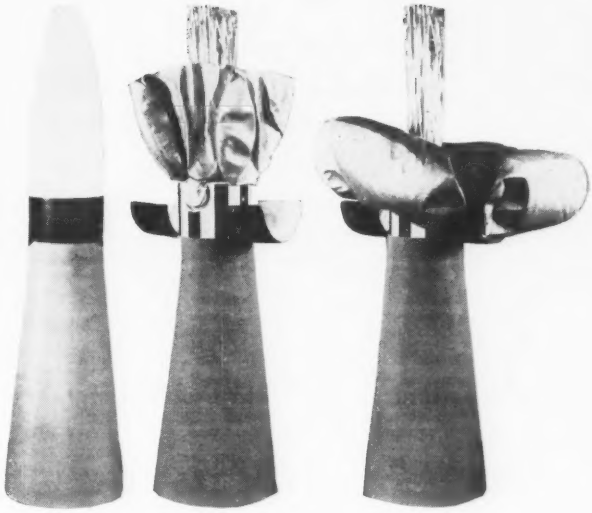
seeking out and solving the problems which lie in the way of the eventual development of such a vehicle system. In order to do this in an intelligent and realistic way, however, it has been necessary to consider various design and operational concepts in some detail.

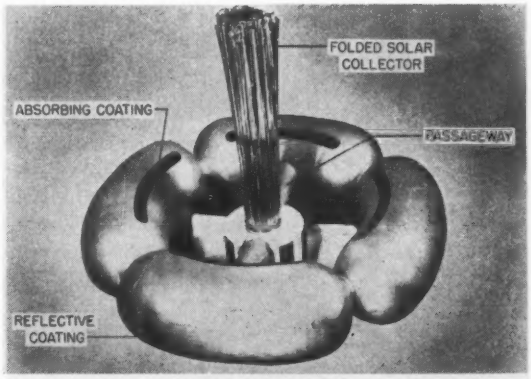
Before discussing conceptual designs which have been considered, let us review some requirements which have been used as a guide for the design of a space laboratory, such as the following:

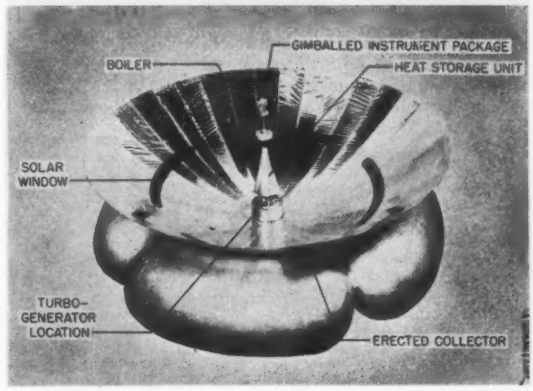
1. Minimum assembly in space, because we are just beginners in this work.
2. Powerplant incorporated to give continuous power to operate the laboratory, communications, etc.
3. Adaptable as booster payload package. The nature of rockets and air drag tends to dictate a cylindrical payload package and influences the station configuration.
4. Rotation:
   (a) The station is to rotate for artificial gravity and not rotate for zero g. Thus the argument is not made for artificial gravity or for zero g, but either can be provided at the will of the occupants. Also, certain scientific experiments might dictate that the laboratory remain stationary at times.
   (b) Dynamically stable about axis of rotation: This requirement means the station should turn about its major axis of inertia, so that it will not tumble if the stabilization system goes off. This requirement has a considerable effect on the arrangement of major components.
5. Space-to-earth taxi always available for safety.
6. Adequate communications.
7. Comfortable human environment for extended periods.
8. Station should have growth potential.
9. Reasonable lifetime in orbit.

With these requirements in mind, the specifications for the design of the station follow:

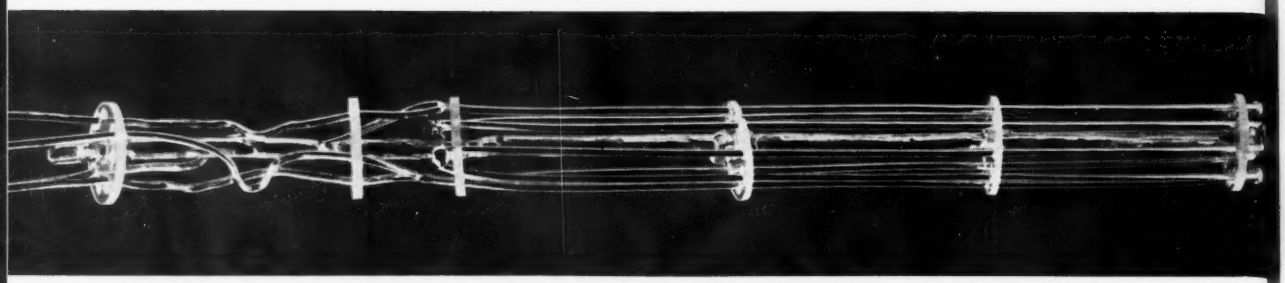
1. Orbit altitude (circular) of 400 miles; this altitude was chosen to keep the station below the Van Allen radiation belt and above the region of high air drag.
2. A minimum lifetime in orbit of 1 year; it has been calculated, however, that a station of the kind contemplated will not come down, due to air drag, for 5 years. Conversely, to maintain the orbit requires the yearly expenditure of propellant equal to less than (CONTINUED ON PAGE 56)







Top, the white cone and black stripe represent an automatically erecting station as mounted on the launch vehicle's final stage; the nose cone ejects and the torus expands to the form shown in the photo second from top; and finally, a solar collector unfolds, presenting the station in its operating configuration.



This NBS-developed platinum resistance thermometer is expected to provide new precision in temperature measurements between 630.5 and 1063 C.

New standards for the Space Age

Space technology has brought need for increasing the accuracy and extending the range of nearly every standard measurement

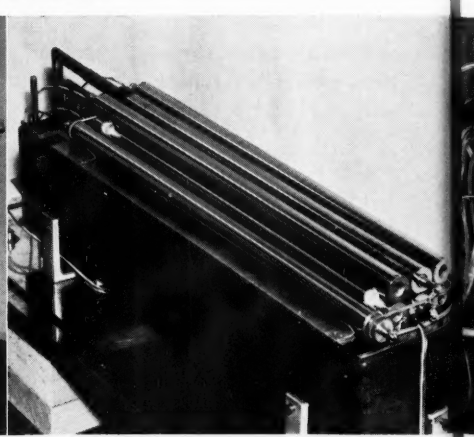
By A. T. McPherson

NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C.

A. T. McPherson is associate director for engineering of NBS, in charge of testing, calibration, and specifications. His background includes a bachelor's degree from Trinity Univ., a master's from the Univ. of Texas, and a doctorate in chemistry from the Univ. of Chicago. A career member of NBS, having been appointed to the staff during World War I, Dr. McPherson has done research in a number of fields—organic and gas chemistry, dielectrics and electrical insulation, rubber, high polymers, etc. For a number of years he served as chief of the Bureau's Rubber Section and later as chief of the Div. of Organic and Fibrous Materials. One of his current assignments is chairman of the NBS Board of Civil Service Examiners. Dr. McPherson is active in several societies and is past president of the Washington Chapter of the Academy of Sciences.

JET AIRCRAFT, missiles, satellites, and the many less glamorous products of the Space Age all depend on precision measurement for the successful assembly and harmonious functioning of their myriad components. Measurements, in turn, require standards, and standards, to be valid, must be derived from national or international standards. Unfortunately, the national standards maintained by the National Bureau of Standards have not kept pace with the rapidly accelerating needs of science and industry, with the result that there are pressing needs to increase the accuracy and extend the range of nearly every standard of measurement.

Below left, a convenient Mercury-198 lamp (being held) serves as light source for wavelength standard of length; krypton-86 lamp on stand is an example of light source for new international wavelength standard of length. Right, the calculable-capacitance standard on which NBS will base a new realization of the ohm and volt.

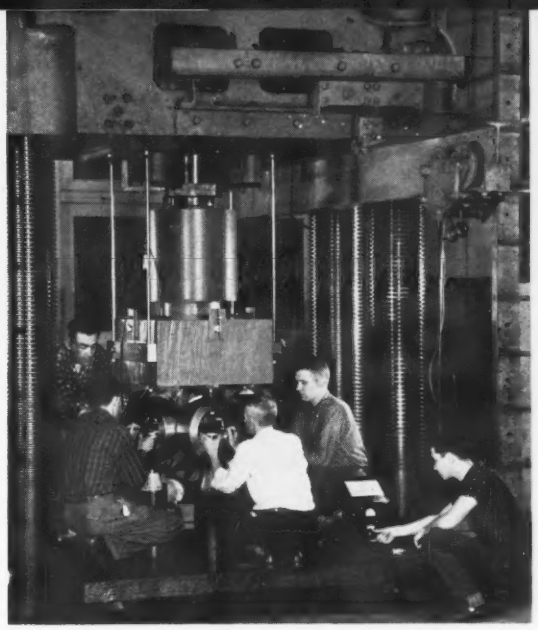


Two factors have combined to push the requirements for accuracy in some areas almost to fantastic limits. One is the increased accuracy that engineers are specifying for a great many items, ranging from guidance systems for missiles to pistons and cylinders of automobile engines. A second factor is the lengthening chain of calibration from the national standard to the workbench in the shop or the instrument panel in the bunker at the launching pad. With each stage of calibration there is a significant loss of accuracy (except for a few measurements), so that the lengthening of the calibration chain in itself would usually necessitate greater accuracy of the national standard even if no greater accuracy were required for the work.

In the early 1900's, it was possible to send every important measuring instrument in the United States to the National Bureau of Standards for calibration. That period came to an end with the industrial expansion and technological development that accompanied World War I. The decentralization of calibration services began then and has continued until now, when we see elaborate systems of standards laboratories being established both in Government and in industry.

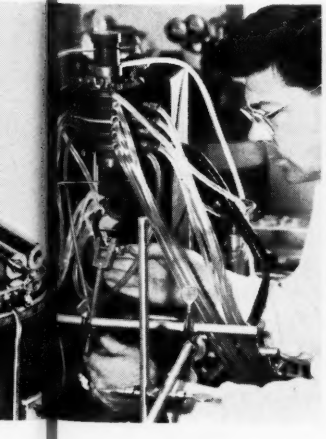
The measuring instruments that require periodic checking number in the millions. The necessary standards and standard instruments must be available on the spot in local standards laboratories. These local laboratories are coming to be so numerous that it is not practical for them to deal directly with the National Bureau of Standards. Instead they obtain their standards through one or more echelons of reference standards laboratories.

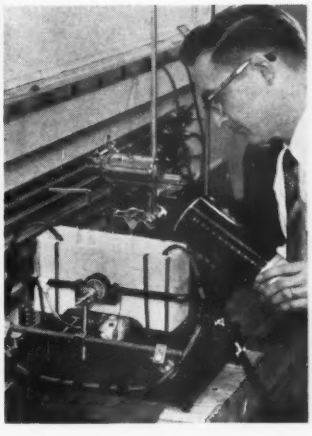
Thus, the over-all system of standards of the nation resembles a great pyramid. The National Bureau of Standards is at the apex of the pyramid. Immediately below the Bureau are the central laboratories of the military services and the corporate standards laboratories of large industrial organizations. Below these key laboratories there are one, two, or even three echelons of reference standards laboratories. At the base of the pyramid are the working standards laboratories that calibrate the end-use measuring instruments. This function is often combined with main- (CONTINUED ON PAGE 50)



NBS engineers calibrate a 1.5-million-lb-capacity load cell (vertical cylinder above large block) that will be used in static tests of giant rocket engines such as the Saturn booster.

Research activities at NBS: From left, adjusting high-temperature furnace developed to maintain a controlled arc in any atmospheric composition; testing setup for studying possible sources of error in a new transfer resistor that will have the same value with AC as DC; preparing a mercury cell whose beams can be collimated in a new way to provide an improved standard of length; and, last, preparing a new cesium-beam frequency standard for operation.

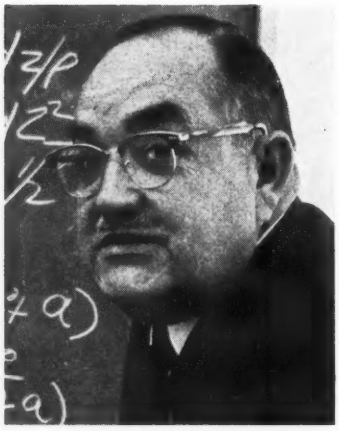




The Operations Room of the Instrumentation and Range Safety System.

Design factors for a missile range

The broad spectrum of instrumentation for a major facility, such as the Pacific Missile Range, reflects both present development needs and a variety of missions to come



By B. F. Rose Jr.

AETRON, A DIVISION OF AEROJET-GENERAL CORP., COVINA, CALIF.

Benjamin F. Rose Jr. is manager of Aetron. A graduate of the Univ. of Illinois with a degree in civil engineering and a registered mechanical and civil engineer in several states, he started his career with the Chicago Bridge and Iron Works; continued at Lockheed as chief planning engineer, responsible for integrating all prime factors essential to efficient project engineering; moved to Douglas as assistant plant manager, his work there including maintenance of production facilities and design and construction of new facilities; and finally joined Aerojet-General in 1947, where he has advanced steadily from design engineer to his present position, in which he has a major part in the direction of Aetron's work in the architectural engineering and electronic fields.

THE MAGNITUDE of a missile range is far greater than its downrange expanse over the ocean. The master plan calls for a large area of land, specialized facilities, highly qualified personnel, adequate but careful funding, and exceptional coordination of these.

The functions of a missile range may include not only the acquisition of test data for research and development, but also the activation of space programs, the training of personnel, and the capability of launching retaliatory missiles. In a broad sense, it is a proving ground for men and missiles.

Set-up at Pacific Missile Range

The Pacific Missile Range in California provides an appropriate illustration of the relation of design factors to missions.

Under management control of the Navy, the Pacific Missile Range (PMR) is divided into five basic subranges—Sea test, IRBM, ICBM, Polar, and Anti-missile. Stationed at the Naval Missile Center, Point Mugu, Calif., about 80 miles north of Los Angeles are the Commander, Pacific Missile Range (Bureau of Weapons), and deputies for Navy, Army, Air Force, and NASA, plus a Marine liaison officer. Facilities there provide means for a number of air, ground, and offshore missile operations. A satellite-launching facility for PMR is at the Naval Missile Facility, Point Arguello, some 90 miles up the coast from Point Mugu. Adjacent to the Point Arguello installation is the 64,000-acre site of Vandenberg AFB.

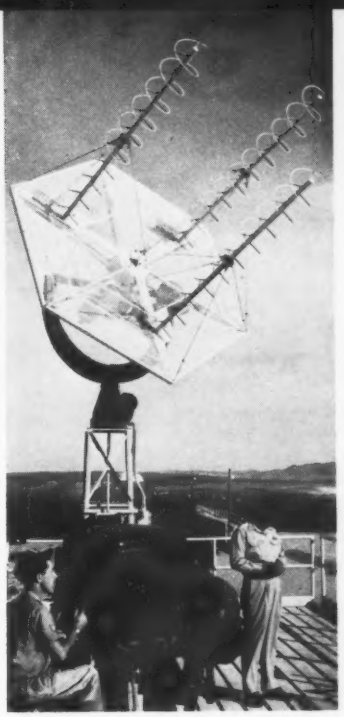
The AF is presently the largest user of PMR. The 1st Missile Div.

has been assigned the responsibility of training the operational manpower for SAC's ICBM sites throughout the nation. Its achievements in operational training and readiness for the Thor and Atlas systems were made in compressed time schedules. Titan and Minuteman are on the agenda. Since December 1958, more than 27 launches have been made and more than 1500 crew members have been trained in addition to training maintenance technicians in the various areas of operation.

Aetron participated in the preliminary planning of PMR and provided services of design, fabrication, supervision of construction, and the implementation of various facilities with structures, roads, utilities, and instrumentation systems at Point Mugu, Point Arguello, and Vandenberg.

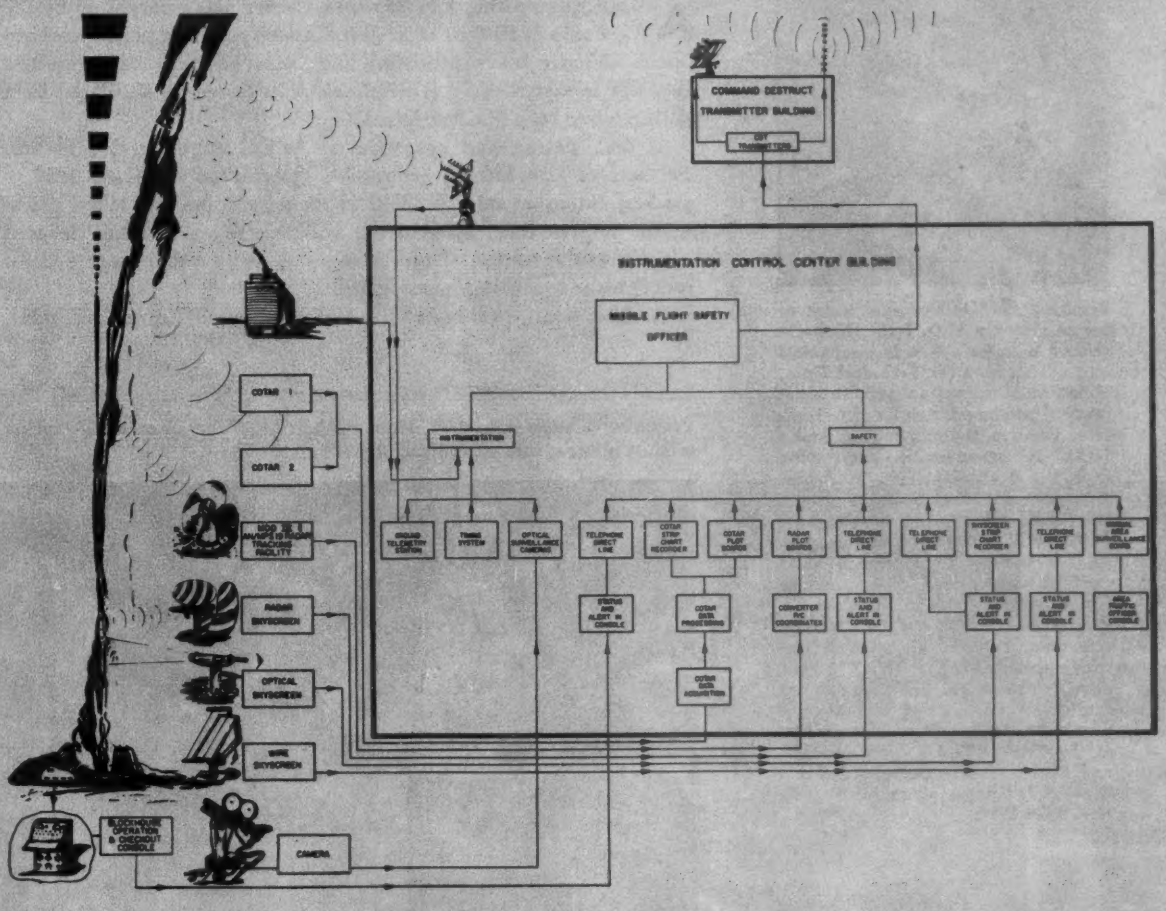
To implement the means for acquiring flight data and to fulfill the requirements for range safety (including the surveillance of air, land, and sea traffic), Aetron performed complete services for the provision of the Instrumentation and Range Safety System (IRSS, subsequently designated Missile Flight Safety System, MFSS) at Vandenberg.

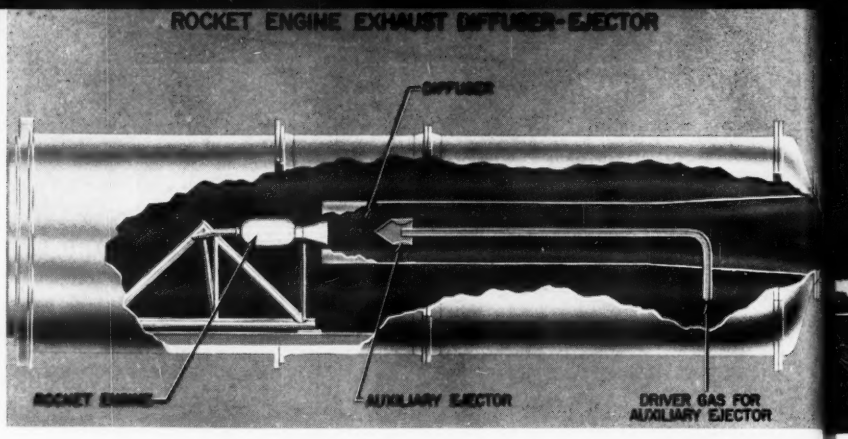
The project at Vandenberg was under the direction of the AF Ballistic Missile Div. The system philosophy and over-all system management responsibility was assigned by the AF to Space Technology Laboratories. Aetron furnished (CONTINUED ON PAGE 94)



A tri-helix telemetry antenna on target.

Instrumentation and Range Safety System, Vandenberg AFB





AEDC developed this diffuser-ejector arrangement to augment test cell's ability to simulate altitude effects, especially during rocket ignition and burnout.

Simulated-altitude rocket testing

Test facilities and techniques developed at AEDC have solved key problems of liquid and solid rocket design

Bernhard H. Goethert is director of engineering for ARO, Inc. His background includes a B.S. in mechanical engineering from the Technical Univ., Hanover, Germany; an M.S. in aeronautical engineering from the Technical Univ. in Danzig, Poland; and a Ph.D. in aeronautical engineering from the Technical Univ. in Berlin. Before coming to this country in 1945, Dr. Goethert held several major posts in the DVL Research Institute of Berlin, his last being department chief for high-speed aerodynamics. Before joining ARO in 1952 as head of the Propulsion Wind Tunnel, Dr. Goethert was consultant and section chief for wind-tunnel testing at WADC, performing theoretical and experimental studies on wind-tunnel testing; and then, with ARO, was appointed chief of the Engine Test Facility in 1956 and held that position until he was appointed director of engineering in November 1959.

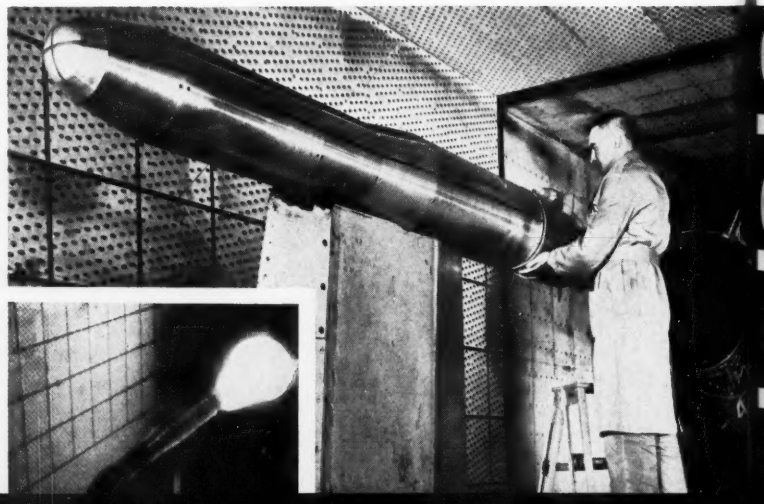
By B. H. Goethert
ARO, INC., TULLAHOMA, TENN.

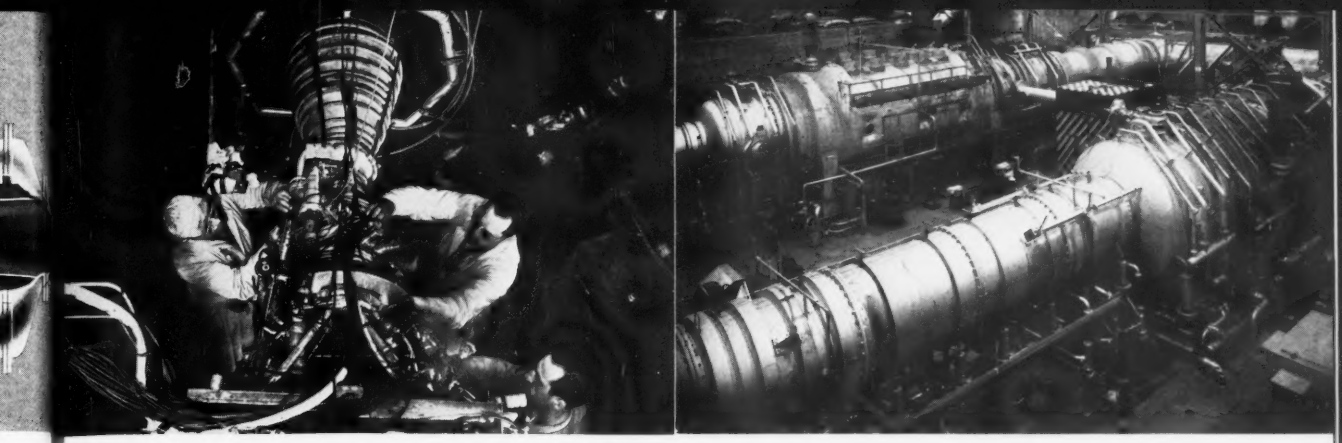
ARNOLD Engineering Development Center was established by the Air Force in 1949 to assist in the development of high-speed airplanes and missiles by providing large wind tunnels and engine test facilities in which these vehicles could be tested at simulated high altitudes and high Mach numbers.

At first, design and operation of AEDC engine test cells was directed at airbreathing propulsion systems only. Since 1957, a gradual extension into the field of rocket engines has taken place. At the present time, three of the available seven cells are devoted entirely to the testing of rocket engines, and another large cell for rocket testing, is going into operation.

To date, a large variety of full-scale and model liquid- and solid-

Preparing a scale model of Titan for testing. The inset shows rocket exhaust blasting into scavenging scoop.





Left, a complete Bell Aircraft 8048 liquid engine sits in a test cell while preparations are made to run it through a cycle of ignition, shutdown, "orbital coast," during which it cools to 30 F, and re-ignition. Right, two of AEDC's seven test cells.

propellant rocket engines with thrusts as great as 60,000 lb and burning times as long as 5 min (with maximum total impulse on the order of 3,000,000 lb-sec during long-duration firings) have been tested in these cells. Some 740 full-scale and model rockets —310 solid and 430 liquid propellant—have been fired at simulated altitudes of 100,000 ft and above.

After the preliminary testing of small rocket engines at AEDC, the first significant test of a full-scale solid-propellant rocket took place in June 1958. At that time, the AF Ballistic Missile Div. and Space Technology Laboratories were jointly preparing for the Able-Thor lunar shots. They found that conventional sea-level facilities were inadequate to determine the total impulse of the third-stage solid-propellant rocket at the expected altitude of operation to the unusually high accuracy required.

Subsequently, the project of impulse determination was given to the AEDC. One of the test cells was modified on a crash basis. Rocket support equipment and measuring instrumentation were selected; altitude-increasing ejectors and diffusers were installed. After a preparatory time of only six weeks, the first firing took place.

The first tests revealed a number of altitude problems which had been unknown previously and had not been anticipated by sea-level testing or theory. These tests also demonstrated for the first time that some of the problems associated with the operation of rocket vehicles at high altitudes can be solved by full-duration firings of rockets in ground test facilities at simulated altitude instead of by actual launchings of full-scale vehicles.

Irregular Burnout Characteristics

In these initial tests, and in numerous subsequent tests of other solid-propellant rockets, irregular burnout characteristics were discovered, as well as ignition unreliability and overheating of the rocket structure, which sometimes led to destruction of case and exhaust nozzle.

In later tests, solid particles in the exhaust of rockets using aluminized propellants were found to cause serious erosion of nozzle elements, separation of flow in the nozzle, and performance losses which could only be determined at high-altitude conditions. (CONTINUED ON PAGE 40)

Left, the first large solid engine tested in an AEDC cell was a Thor-Able third stage (ABL's X-248), shown here being mounted for a test; insets (top to bottom) show a chuffing sequence. Right, results of testing a solid rocket with a proposed plastic nozzle at a simulated high altitude; insets (top to bottom) show nozzle deterioration.

The U.S. ion propulsion program

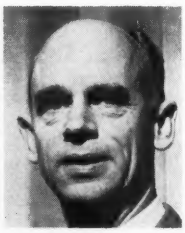
Capt. Richard Hayes
HEADQUARTERS, NASA, WASHINGTON, D.C.

Robert N. Seitz
GEORGE C. MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA.

Ernst Stuhlinger,
GEORGE C. MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA.

Capt. Richard J. Hayes, "on loan from the AF," is currently assigned to NASA as a specialist in electrical propulsion. After receiving a B.S. degree in mechanical engineering from MIT in 1954, he became an AF jet-fighter pilot and was assigned to ARDC in Dayton, Ohio. As a result of an AF-sponsored graduate school program, Capt. Hayes was awarded an M.S. in aeronautics and astronautics from MIT in June 1960. He is a co-author of the 1960 ARS-Thiokol Chemical Corp. award-winning paper in astronautics.

Robert N. Seitz has engaged in ion propulsion research and contract supervision at MSFC's Research Projects Div. since 1958, when he received an M.S. degree in physics from Case Institute of Technology. From 1954 to 1956, he was associated with Brennan Laboratories, where he participated in electron bombardment studies; and from 1956 to 1958, he was a member of the Case staff, concerned with theoretical work in algebraic topology and with some feasibility studies of ion propulsion.



Ernst Stuhlinger, Director of the Research Projects Div. of MSFC, received his doctorate in physics at the Univ. of Tuebingen, Germany, in 1936, and was assistant professor of physics at the Berlin Institute of Technology, doing research in nuclear physics, from 1936 to 1941. He joined the Peenemuende Rocket Development Center in 1943 and was active in the development of V-2 guidance and control systems. Coming to the U.S. under Army Ordnance Corps auspices in 1946, Dr. Stuhlinger did R&D work on missiles at Ft. Bliss and assisted in the V-2 firings at White Sands before joining ABMA in 1950.

THE FASCINATING worlds of outer space are being explored by scientific payloads which are launched from the Earth's surface by large chemical rockets. The desire to increase the size and weight of the deep-space probes in order to achieve eventually manned interplanetary travel will result in the design of enormous launch vehicles. There will be a time when we have reached an upper limit in the size of launch vehicles beyond which a vehicle would be too large, too heavy, and too unmanageable to be of practical use.

Fortunately, this limitation does not force us to restrict our thinking to a maximum size spacecraft for interplanetary travel. By using an electric engine in the spacecraft, it will be possible to greatly increase the weight that can reach the destination planet.

Electric engines are characterized by low thrusts relative to their weights, high exhaust velocities, and low mass-flow rates. These features result in long operating times in order to achieve the necessary terminal velocity required for ambitious interplanetary missions. Although the electric engines now under development are still in their infancy, the interest in this challenging and promising propulsion field has witnessed an enormous growth. Ten years ago, the field of space propulsion was practically unknown, and five years ago there was only a handful of technical articles on the subject. Today, there are hundreds of technical papers, and many varied research projects are underway in industry and at universities.

We at the National Aeronautics and Space Administration are striving to make electric engines an integral part of this country's space exploration and utilization program. A considerable amount of work has been done in the last few years, but much more remains to be accomplished before we will witness manned interplanetary travel via an electrically propelled spaceship. Let us consider the present status of electric engine development.

The electric engines planned for space propulsion are commonly classified into three categories: Electrostatic or ion, electrothermal or arc jet, and electromagnetic or MFM. All three types are planned for different missions, and are being developed independently.

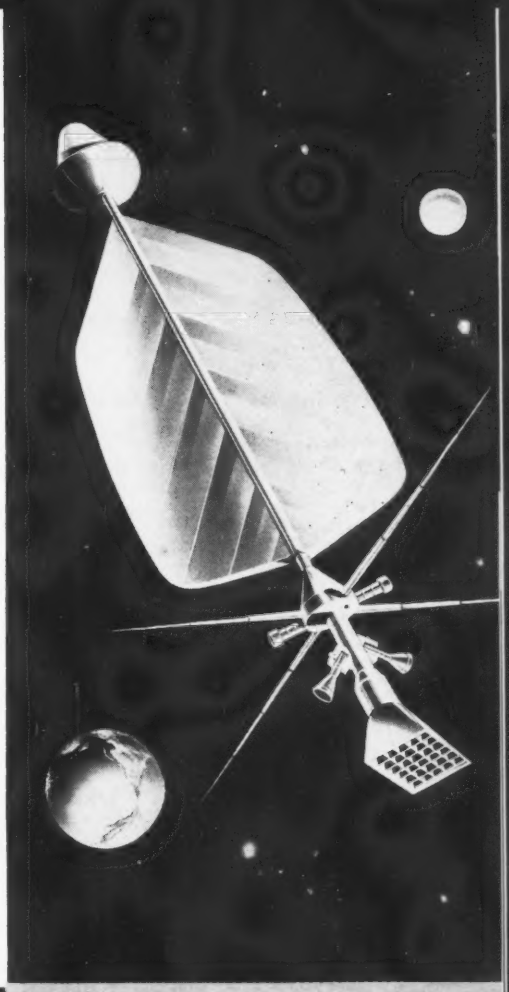
However, the arc jet and ion rocket programs appear to be closer to flight status than the MFM accelerators.

Space Electric Power Supplies

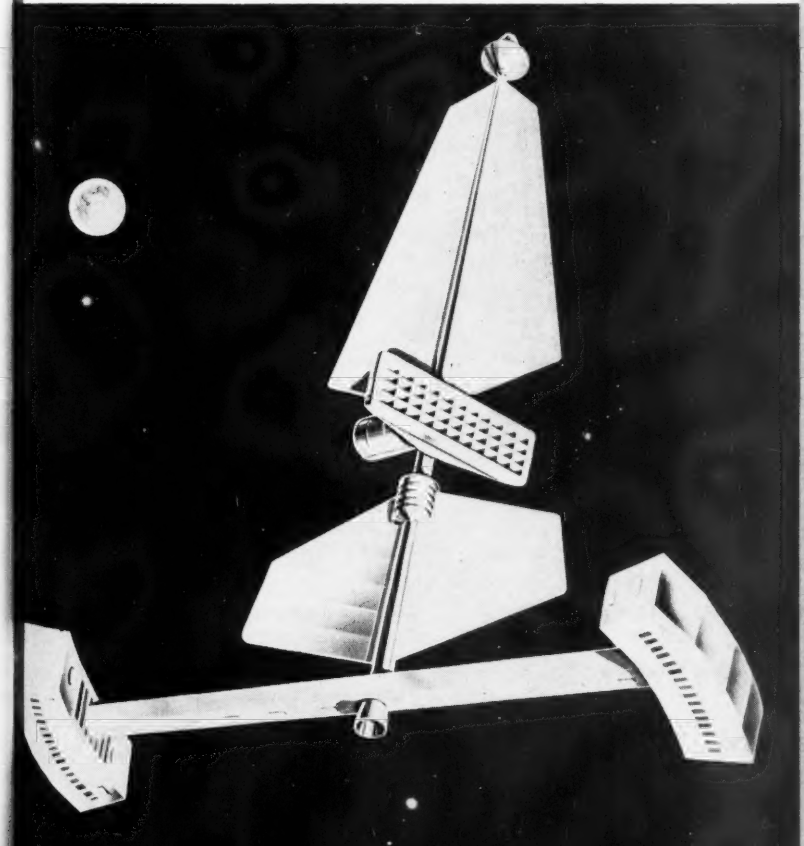
In common with other electrical propulsion systems currently under development, the ion rocket requires an electric power supply suitable for space applications. Nuclear-electric power supplies will be most commonly used for this purpose. These will consist of a nuclear reactor, a thermal-to-electrical power converter such as a turbogenerator or a thermionic converter, and a radiator to dissipate the low temperature heat rejected during the thermodynamic cycle. The drawing on page 91 shows a schematic of such a power supply.

So far, these systems are still quite heavy with respect to their useful power output. For example, the 3-kw Snap II and 30-kw Snap VIII power supplies currently under development under joint NASA-AEC sponsorship have power-to-weight ratios, including minimum shielding, of 0.0075 kw/kg and 0.03 kw/kg, respectively. This restricts electrical propulsion systems to low acceleration applications in space. Of course, these power-to-weight ratios will undoubtedly improve with the passage of time. It is interesting to observe that, over the last two years, the most optimistic power-to-weight engineering estimates have risen from 0.2 kw/kg to a little more than 0.55 kw/kg.

But even with improvements beyond the 0.55 kw/kg value, the accelerations which can be obtained with electrical propul-



Artist's conception of a deep-space ion-propulsion probe.



Artist's conception, at left, is of an electrically propelled manned Mars ship, capable of delivering 150 tons of payload into a satellite orbit around the planet.

STATUS OF THE ION PROPULSION EFFORT*

Contractor and Project Managers	Source	Contract Number	Level of Support (Millions)	Duration	Started	Remarks
Aerojet-General						
(Edmonson)	AFOSR	AF49(638)-656	$0.094	12 mos.	March '60	Basic studies of charged oil droplet formation
(Sunderland)	AFOSR	AF49(638)-214	.085	12 mos.	June '60	Hohlraum source (includes neutralization and negative ion generation)
Allison						
(Rosebrock)	In-house effort					Theoretical analysis
Convair-Ft. Worth						
(Spearman)	In-house effort					Duoplasmatron development
EOS	WADD					
(Forrester)	(ARPA)	AF33(616)-6958	1.190	15 mos.	March '60	Alkali metal ion engine. Classified objectives
(Teem)	NASA	NAS5-604	.084	12 mos.	Sept. '60	General investigation of copious and efficient negative ion sources
GE						
(Baldwin)	NASA	NAS8-29				Included in ion rocket performance evaluation
(Edwards)	NASA	NAS8-29	.015	3 mos.	Aug. '60	Cesium ion rocket performance evaluation, neutralization studies (Continuation of ABMA contract)
(Edwards)	NASA	NAS8-623	.043	12 mos.	Oct. '60	Alternate ion optics-computer program
(Stauffer)	NASA	NAS8-624	.043	12 mos.	Oct. '60	Electrical conduction in cesium vapor
GHVA						
(Nablo)	WADD	AF33(616)-7178	.280	12 mos.	March '60	Duoplasmatron. Classified objectives (Study of change exchange neutralization)
Hughes						
(Currie)	NASA	NAS5-517	.490	12 mos.	Oct. '60	Alkali metal ion engine. Classified objectives
Marquardt						
(Pitkin)	In-house effort				———	Sputtering, secondary emission, digital-computer beam studies
Martin	In-house effort				———	Theoretical analysis
NASA Lewis						
(Childs)	In-house effort					General R&D, 15 man years plus equipment
(Kaufman)	In-house effort					Bombardment type ion engine
Pratt & Whitney (UAC)						
(Meyerand)	In-house effort					Penning source, general research
Reaction Motors						
(Wolfhard)	AFOSR	AF49(638)-657	.153	12 mos.	Dec. '59	Behavior of metallic dust during charging process
Rocketdyne						
(McDole)	In-house effort					Continuation of program prposed to NASA
(McDole)	WADD	AF33(616)-5927	.100	12 mos.	June '60	Pore size, materials, Cs vapor pressure, field gradient at surface of emitter
(McDole)	WADD	AF33(616)-7622	.100	12 mos.	June '60	
STL						
(Krohn)	WADD	AF33(616)-6775	.137	18 mos.	Aug. '59	Basic studies of charged droplets of liquid Wood's metal
(Langmuir)	NASA	NAS8-41	.097	12 mos.	Oct. '60	Ion-atom ratio; surface diffusion coefficient of Cs on W; shaping; emission dependence on pore size, density, temperature, etc.
TRW						
(Langmuir)	AFOSR	AF49(638)-886	.092	12 mos.	May '60	General neutralization studies
TRW (Tapco)						
(French)	NASA	NAS8-42	.092	12 mos.	Oct. '60	Annular duoplasmatron, improvement of 3-in. diam source; continuous operation

* The authors wish to acknowledge the efforts of E. W. Urbar and J. W. Rowland in preparing the tables on pages 32-33.

sion systems will still be less than 10^{-2} G. For this reason, any type of propulsion system which requires a self-contained electrical power supply will be unable to take off from the ground, and will be suitable only for low-acceleration space-flight operation. This fact is important in comparing ion and MFM rocket engines for equivalent space missions. It is sometimes argued that MFM accelerators are inherently superior to electrostatic accelerators because of the lower accelerator weights which characterize them. However, the real "bottleneck" in electric propulsion systems is the weight of the electrical power supply. The electrostatic propulsion devices currently under development will weigh very little compared to the power supplies required to actuate them. Therefore, the higher thrust-to-weight ratios which MFM accelerators are inherently able to provide cannot be effectively utilized to reduce the weight of the complete propulsion system to much less than the weight of an equivalent ionic propulsion system.

The 3-kw Snap II power supply is currently under development by Atomics International and Thompson Ramo Wooldridge corporations, and is scheduled for a first flight in 1964. The 30-kw Snap VIII power source is being developed by Aerojet-General and Atomics International and will be flight-tested in 1965. Power output from both of these supplies can be doubled with moderate additional weight. A key question with turbogenerator power supplies is that of reliability and freedom from maintenance over the year or so of continuous operation required for space-propulsion applications.

It is generally conceded that the development of a reliable, lightweight, flyable nuclear reactor with a direct thermal-to-electrical power-conversion device (such as a thermionic converter) would be very desirable for the electric propulsion program. Research on nuclear reactors and energy-conversion devices is proceeding independently of engine developments, and we hope that power sources which are markedly advanced beyond the first-generation Snap VIII will be available by 1970.

Artist's conception of an Earth-Moon tugboat.

Among the applications which appear to be suitable for ionic-propulsion systems are the vernier control of satellite orientation and orbital parameters; the interorbital transfer of large satellites; the repeated ferrying of payloads from the Earth to the moon; interplanetary propulsion to and from Mars and Venus; deep-space probes which would closely approach the sun or the orbits of the outer planets; travel out of the plane of the ecliptic; and probes to the outer planetary regions.

Ion rockets will be useful for the vernier control of satellite orientation, the correction of orbital injection errors, the elimi- (CONTINUED ON PAGE 90)

COMPLETED CONTRACTS, ION PROPULSION

Contractor and Project Managers	Source	Contract Number	Amount	Duration	Started	Remarks
EOS						
(Naiditch)	ABMA ARPA	DA-04-495-ORD-1191 (part 1)	.319	28 mos.	March '58	Investigation of ionized gases
(Naiditch)	ABMA ARPA	" (part III)	.189	16 mos.	March '59	Acceleration systems for ion propulsion
GHVA						
(Gale)	ABMA	DA-19-020-ORD-4969	.085	14 mos.	June '59	Ion thrust devices (duoplasmatron)
Rocketdyne						
(Boden)	AFOSR	AF49(638)-344	.090	?	March '58	Analytical study of ion propulsion
(Boden)	AFOSR	AF49(638)-361	.193	24 mos.	May '58	Ion propulsion research
STL						
(Langmuir)	WADD (ARPA)	AF33(616)-5919	.200	12 mos.	May '60	Included in mission study contract

Advances in electrostatic propulsion

By A. T. Forrester and J. M. Teem

ELECTRO-OPTICAL SYSTEMS, INC., PASADENA, CALIF.

Cesium-ion motors coming along, gaseous-discharge sources encouraging, beam neutralization a question, flight-testing plans here . . . .

Forrester Teem

A. T. Forrester is head of the Ion Physics Dept. at Electro-Optical Systems, Inc., where he is directing the ion propulsion program. Prior to this association, he directed the experimental program in ion propulsion at Rocketdyne. After receiving a Ph.D. in physics from Cornell Univ. in 1942, in high-intensity ion sources and electromagnetic methods of separating isotopes, Dr. Forrester worked at Berkeley and Oak Ridge on the electromagnetic separation of uranium isotopes, and then with the Univ. of Southern California and Westinghouse Research Laboratories.

J. M. Teem is principal scientist of the Fluid Physics Div. of EOS, where he is currently engaged in research work in the area of alkali ion propulsion, on formation of halogen ions on low work function surfaces, and on cesium charge exchange scattering, in addition to staff work on a company level. He received a Ph.D. degree from Harvard Univ. in 1954, where his thesis and other work concerned high energy proton scattering on light nuclei. Prior to joining EOS, Dr. Teem was a member of the physics faculty at the California Institute of Technology for six years. There he was active in high energy particle physics research as well as teaching, and his work contributed to the design and operation of the CIT 1.3 Bev electron synchrotron. He also headed the group which developed a new type of heavy liquid bubble chamber, using tungsten hexafluoride, which was used for photomeson production experiments.

THE FIRST ARS Specialist Conference in Electrostatic Propulsion, held at the U.S. Naval Postgraduate School, Monterey, Calif., on Nov. 3–4, 1960, provided an informative and stimulating interchange between engineers and scientists from most of the laboratories engaged in the various aspects of this field. Though some projects were not represented, the organizers of the conference—Ernst Stuhlinger, David B. Langmuir, and J. M. Sellen Jr.—achieved an optimum compromise among various factors: Thorough coverage, ample presentation and discussion time per paper, a balanced program, single sessions and a length consistent with sustained interest by participants.

Among the conclusions to come out of the conference were that cesium ion motors appear to be operating as well as its proponents have been anticipating in recent years and that the problems of increasing sizes and efficiencies seem to be falling into place.

Various types of gas discharge ion sources, when taken together, occupied almost as much space on the program as the cesium surface ionization sources, and some developments in discharge sources seemed highly significant. Colloidal particle sources, on the other hand, were discussed only in one paper, which concerned a careful study to determine the limitations in the production of charged liquid metal droplets. There were several papers concerned with instruments for the diagnosis of ion motor operation. And, for the most part, it can be stated that progress in electrostatic propulsion is not being impeded by inadequate measuring techniques although some results may be questioned on the basis of the types of measurements performed.

Answers were sought to the problem of neutralization in space, which continues to be the most severely questioned aspect of ion propulsion. A large number of the papers, both experimental and theoretical, were devoted to this subject; and it was pointed out that some sophisticated theoretical approaches are now being taken, but the most thorough of these involve setups on digital computers which have not as yet yielded explicit results. The presence of boundaries in laboratory vacuum chambers creates great difficulties in testing for neutralization on the ground. It was generally agreed that a space test was of compelling importance and there was considerable discussion of space tests. Here follows a summary of some of the significant papers given at the conference.

Cesium Ion Motor Technology

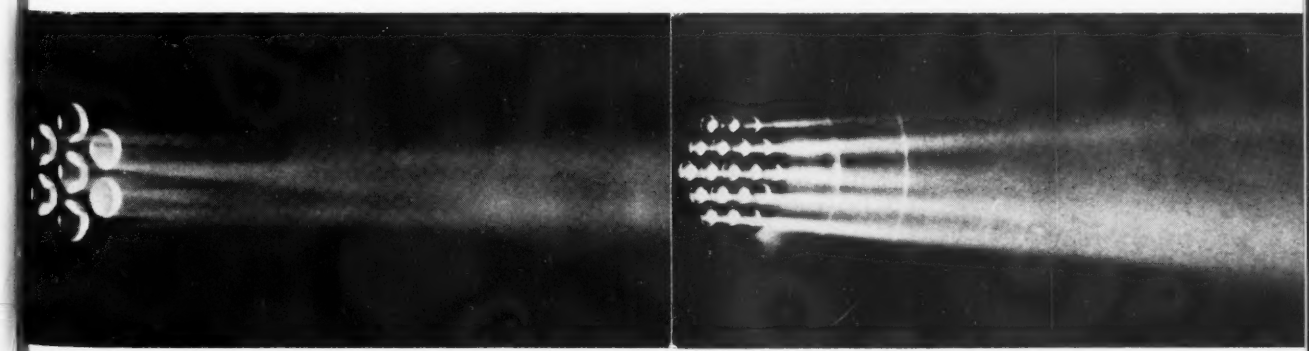
Cesium ion motor technology appears to be developing at an encouraging rate. The eight papers related to this topic covered such aspects as basic surface ionization data, theoretical and experimental work on characteristics of porous ionizers, and motor design and performance. Some of the material presented on the latter topic has been included in a recent state-of-the-art review by D. B. Langmuir (*Astronautics*, November 1960).

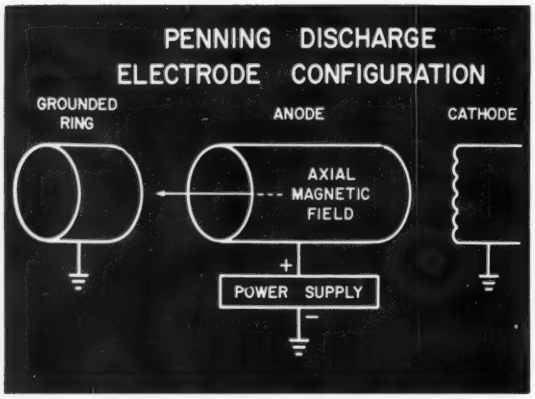
J. E. Etter, *et al.*, of Hughes Aircraft, presented additional data on a single circular ion beam motor employing what was referred to as a "new mechanism of neutralization," which will be described later. The perveance of the acceleration section of this device was 2.79 x 10^{-9} (amps/volt$^{3/2}$), and the anode interception was reported to be less than 0.1 per cent. The maximum current reported was 12.5 microamps, corresponding to a current density at the emitter of the order of 10 microamps/cm^2, and an equivalent perveance of 10.8 x 10^{-9} when referred to the exit voltage. It must be noted, however, that at such current densities the contribution to intercepted fraction arising from charge exchange collisions in the accelerator may be expected to be negligible. It would be interesting to measure the corresponding interception fraction obtained with this particular device at current densities in the range of 1 to 10 milliamps/cm^2, where charge exchange may be of importance. An interesting aspect of this motor design was the use of circulating coolant to control the temperature of the beam-forming, or focus, electrodes.

R. C. Speiser, *et al.*, of Electro-Optical Systems, reported on the operation of multiple beam ion motors containing arrays of seven and nineteen circular beams, shown on this page, which operated at current densities 2 to 3 orders of magnitude higher. By the use of large accel-decel operating ratios, equivalent perveances per single aperture up to 9.4 x 10^{-9} were obtained, calculated from the total current and the potential difference between the ionizer and exit electrode. The seven-beam motor utilized $^1/_4$-in.- diam ionizers while the nineteen-beam motor consisted of an array of $^1/_8$-in.-diam emitters. Current densities in the latter

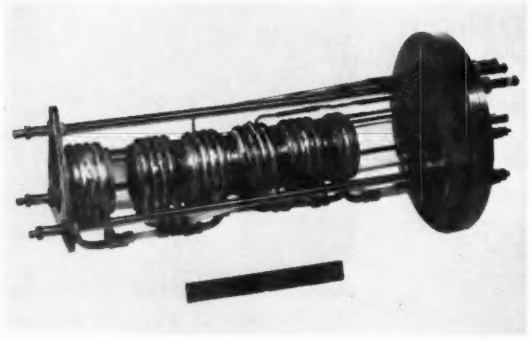
The multiple beam cesium ion motor structure shown here, developed by Electro-Optical Systems, Inc., contains arrays of seven and 19 circular beams.

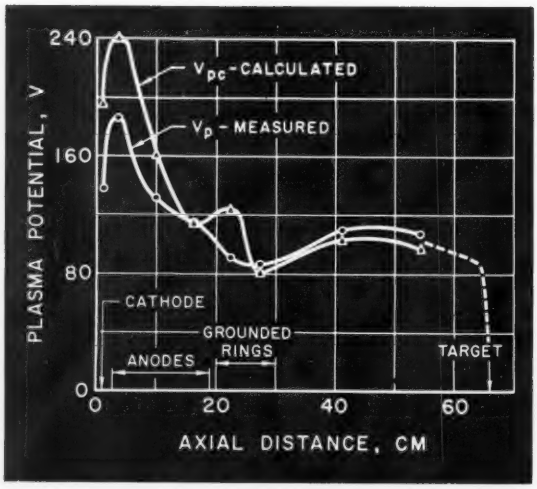
Here, below, are examples of the beam arrays in operation. Photos were taken at pressures of 5 x 10^{-5} mm of Hg.





This is a schematic representation of the United Aircraft Oscillating Electron Plasma Source. Shown below is the electrode assembly of the plasma source; it uses no ion acceleration other than that which exists within the plasma.





Plasma potential in oscillating electron source by probe measurements assumes the shape shown above. V_p is obtained from the knee of Langmuir probe characteristics and V_{pc} is calculated from the floating potential corrected for the measured electron temperature.

case were 9.4 milliamps/cm² of porous ionizer area, or an average density of 3.6 milliamps/cm² for the total exiting beam. Accelerator current drains were considerably higher than those obtained elsewhere, corresponding to intercepted fractions possibly as high as 10 per cent. However, Speiser noted that observation of both the sputtering damage patterns and tests with electrically isolated electrode sections disclosed that most of the current to the accelerating electrode was peripheral to the beam area. An unknown but possibly large fraction of this current may be due to thermionic electrons from the accelerator. It was also noted from the sputtering pattern that most of the ionic contribution to this current apparently arose from ions formed on the focus electrode, which in this case was not cooled. It was considered encouraging that these peripheral drain currents did not increase proportionately to the size of the array.

Effort on Power Optimization Needed

An important criticism of all of the cesium ion motor work reported to date can be raised in that insufficient effort has been made to optimize power efficiency, especially through reducing thermally radiated losses from the emitter structure. The best power efficiency reported by Speiser was 24 per cent, or 30 per cent if the nonbeam region current drains were neglected. Although admittedly the relative thermal losses should go down with increasing motor size, it is apparent that more effort will have to be applied along this direction to develop such devices into feasible propulsion units.

Speiser also reported a thrust measurement from the nineteen-beam array of 0.485 millipound at an $I_{sp} = 11{,}000$ sec. However, the total perveance is a more important parameter, and the highest total equivalent perveance reported in the published literature was that described by Langmuir, in the *Astronautics* article, 4×10^{-7} (corresponding to a thrust of 0.57 millipounds at the more desirable $I_{sp} = 5500$ sec). This was obtained for a motor similar to that described by J. M. Sellen Jr. and H. Shelton, of Thompson Ramo Wooldridge, in connection with their paper on the transient and steady-state behavior of cesium ion beams. This motor used carefully aligned fine wire grids over a 1-in.-diam-porous emitter and thus does not appear to have the ruggedness required for a long-lived ion engine.

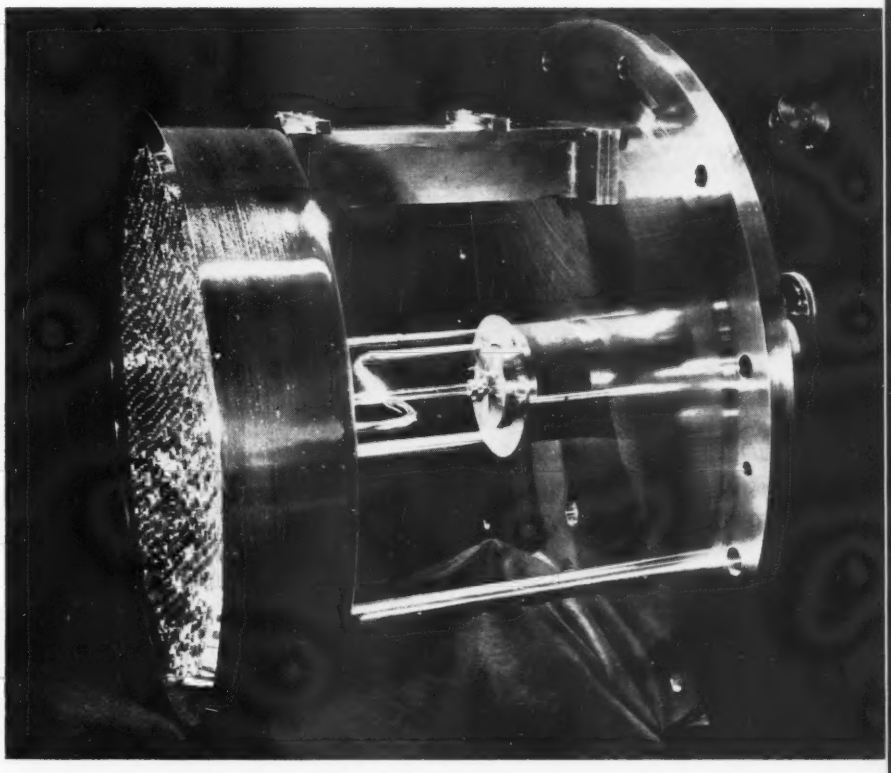
In the EOS work reported by Speiser, beam neutralization was accomplished without "deliberate" injection of electrons, and the TRW work reported by Sellen examined in detail the mechanisms by which such charge neutralization was accomplished by trapped secondary electrons. Also

studied was the mechanism of establishing current neutralization as well by electrons injected from either a hexagonal electron Pierce gun or a simple button emitter. For the latter experiments a floating collector was used, which showed that the plasma potential always adjusted itself to that required to pull sufficient electrons into the beam from the electron emitter to produce zero total current. The transient beam behavior and the neutralization questions raised by these experiments are discussed later on.

Phenomena connected with cesium surface or contact ion sources were discussed from several viewpoints. D. G. Worden, of General Electric Research Laboratories, described some well-executed experiments for obtaining basic surface ionization data for cesium on molybdenum, using both pulsed atomic beams and periodic variation of the ion collecting field. A value for the binding energy of cesium on polycrystalline molybdenum of 1.78 ev was reported, which is about 0.2 ev less than that on tungsten. It seems apparent that more such work extending the pioneer work of I. V. Langmuir and others would be worthwhile to the cesium ion motor program.

Four papers dealt with porous tungsten ionizers. E. N. Petrick, of Kelsey-Hayes, defined the problems of fabricating and joining porous tungsten emitters. He reported success in using pure platinum as a brazing material. G. M. Nazarian and H. Shelton, of TRW, and D. Zuccaro, *et al.*, of EOS, reported on similar calculations of the transport of cesium through and onto the surface of porous emitters, leading to estimates of the neutral fraction resulting. Both papers considered the problem in terms of the ratio of diffusion length, that is, the distance an atom travels by surface migration within an adsorption lifetime to the average pore diameters and spacing. Nazarian treated the transport as the simple sum of Knudsen and surface diffusion flows, and used his results to set criteria for pore sizes and spacings as a function of temperature, as well as considering criteria for optimum feeding of the cesium. Zuccaro attempted to consider the geometrical aspects entering into the transport equations near the pore exit more exactly, and calculated current densities and neutral fractions expected for a uniform pore spacing model chosen to approximate porous materials in use. Both papers made what may be a poor assumption that only neutral atoms come out of the pores, neglecting effects of field penetration.

Zuccaro and O. K. Husmann, of Curtiss-Wright, reported on measurements (CONTINUED ON PAGE 86)



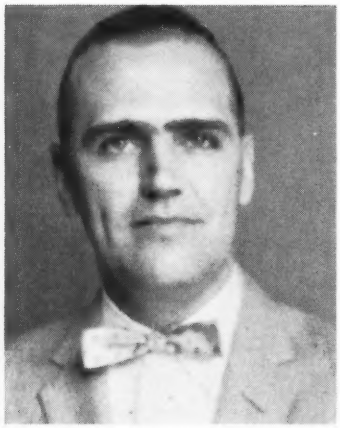
The collector at right, developed at EOS, allows rapid, accurate, absolute measurements of ion motor thrust and current.

Marketing military products

A company market research program specifically aimed at defense problems can be a key to profitable military product development

By Edmund J. Richards

THIOKOL CHEMICAL CORP., BRISTOL, PA.



Edmund J. Richards is manager of market research for Thiokol Chemical Corp., reporting to the director of corporate planning. He is responsible for analyzing and interpreting economic, political, and military factors affecting the present and future activity of the corporation, particularly with respect to the market potential of new products, analyzing the needs and requirements of both military and commercial customers, and assessing the status of competitive companies and products. For the last six years, Richards has worked in the propulsion industry as a market research analyst with Curtiss-Wright, Reaction Motors, and Thiokol Chemical. His analyses of current and future propulsion applications and requirements have covered all types of engines—gasoline, diesel, turbine, ramjet, liquid and solid rocket, and advanced propulsors. He holds B.S. and M.A. degrees from Boston College.

MARKET research has traditionally been associated with toothpaste, soap, appliances, cigarettes, and girdles. However, the defense industry is fast learning that such research can also be used to sell aircraft, missiles, space vehicles, propulsion, guidance systems, and ground-support equipment.

There is an urgent need to improve decision-making tools in the defense industry. All defense contractors have the same basic problems. They are not only selling tangible hardware items but, in many cases, such intangibles as basic research with no end-product in view, new concepts based on anticipated breakthroughs that cannot be guaranteed, and weapon systems involving radical and unproved ideas. The situation is further complicated by the fact that they must deal with a customer whose needs and requirements are subject to sudden and unpredictable changes caused by economic, political, and social events, not only on a national but also on an international scale.

Although risks are inherent in all business decisions, the combination of these factors compounds the problem in the military market. Market research, by its very nature, can and does produce facts with respect to all kinds of goods and services. It can, properly adapted, be used to supply management with the vital tools necessary to enable them to make better decisions in the military market.

The basic responsibilities of market research embrace the problem of assessing the over-all market, determining market requirements, and assisting in product development. Working in these three broad areas, market research can produce qualitative planning data which have immediate use in research and development, marketing, advertising, and production.

The following model shows what market research can provide within the framework of the defense industry:

1. *Assessment of the over-all market*—Through an analysis of the total market, the branches of service and types of weapon systems which use the product, and a determination of company market penetration as well as distribution among the competition by dollar volume and number of programs.

2. *Determination of market requirements*—Through an analysis of weapon-system requirements and roles and missions of the military services.

3. *Aid in product development*—By making sure the product has a current or future application, meets (CONTINUED ON PAGE 77)

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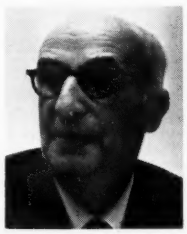

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Letter from Paris

By A. K. Oppenheim

PROFESSOR OF AERONAUTICAL SCIENCES, UNIV. OF CALIFORNIA, BERKELEY

AND VISITING PROFESSOR AT THE SORBONNE, PARIS, FRANCE

PARIS—Astronautics is a great word hereabouts. You can find more in the daily press about the misfortunes of the Mercury program and the successes of the Discoverer satellites than you can about the war in Algeria. On television, an international quiz program, matching teams from Paris and Luxembourg, is about to get underway which will have astronautics—its history and scientific and technical achievements—as its main category.

Frenchmen even seem to have a valid claim to the word "astronautics," many reports noting that it was coined (as "l'astronautique") at one of the famous parties in the Paris home of André Louis Hirsch around the turn of the century. You can read all about it in Andy Haley's book, "Rocketry and Space Exploration," from which you can also learn that some of the first *informed* speculation on interplanetary and interstellar flight, including a consideraton of nuclear propulsion, were propounded by Robert Esnault-Pelterie in a truly amazing article published in the March 1913 issue of *Journal de Physique*.

* * *

Today, the man around whom most of the astronautical elite gathers is the incomparable von Karman. His position is given official recognition in his appointment as Director of the International Academy of Astronautics. Organization of the Academy has already been reported in *Astronautics*, so it is fitting now to introduce some of its officers.

The two Deputy Directors are Prof. J. Peres, Dean of the Faculty of Science at the Sorbonne, and Frank J. Malina, one of the founders of Aerojet, who really needs no introduction to most of our readers.

The Academy is divided into three Sections. Section I, devoted to the basic sciences, is chaired by Prof. A. Ehmert of the Max Planck Institute for the Physics of the Stratosphere in Gottingen, Germany. Chairman of Section II, devoted to the engineering sciences, is Prof. Rudolf Pesek of the Academy for Basic Sciences in Prague, Czechoslovakia, while the Chairman of Section III is Prof. M. Florkin, eminent biochemist at the Univ. of Liege, Belgium.

The Academy's Acting Secretary is A. R. Weiller, who assures me he would cordially welcome visits from ARS members in Paris at the Academy's headquarters, located at 12 Rue de Gramont, Paris 2, phone Richelieu 66.31. (CONTINUED ON PAGE 74)

Simulated-Altitude Testing

(CONTINUED FROM PAGE 29)

Results obtained from high-altitude tests of solid-propellant rockets have indicated that space impulse can be extrapolated theoretically from sea-level test data with accuracies in the order of 1 to 2 per cent for propellants producing the less complex single-phase exhaust gases. However, where the propellants produce multiphase exhaust products, errors in excess of 5 per cent have been experienced.

By systematic high-altitude tests, the expansion characteristics of multiphase exhaust products have been determined. In particular, the approximate size of the solid exhaust particles was determined for some high-performance solid propellants. Knowing particle size and making some theoretical assumptions about the process of their formation, simplified one-dimensional flow theory can predict the particle influence on the exhaust flow and, thus, on the performance of rockets for a large variety of propellants and nozzle geometries. Based on such semi-theoretical calculations and on numerous high-altitude tests, rocket exhaust nozzles have been developed for specific propellants that realize approximately 98.5 per cent of calculated impulse.

These tests have demonstrated the necessity of high-altitude testing where accurate impulse data are required and functional adequacy must be proved. Impulse determinations to accuracies of $^1/_4$ percent or better have been consistently obtained in the AEDC high-altitude experiments.

After tests of various small liquid-propellant rockets, having thrust in the 1000- to 2000-lb class, the first tests of a large full-scale liquid-propellant rocket at simulated high altitude were undertaken at AEDC in March 1959 for the Bell-Hustler engine.

Purpose of Tests

The purpose of this test series was to check the operation of the complete rocket engine package, including gas generator, gas turbine, propellant pumps, control system, etc., particularly with respect to starting and shutdown, as well as restart after both short and prolonged periods of coasting at high altitudes.

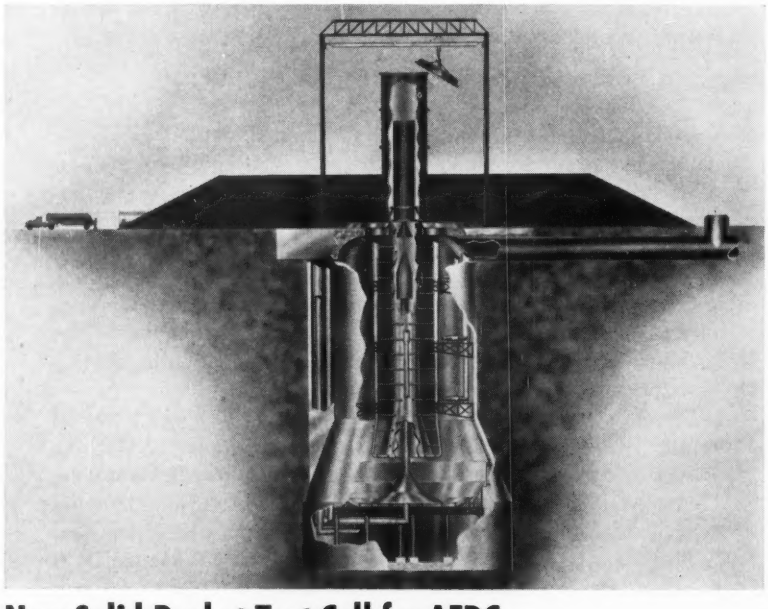
The test series demonstrated the great reliability of this engine at the selected high-altitude test conditions, but it also revealed that the re-ignition capability appeared to approach a functional limit when the temperature of the rocket and the propellants was gradually reduced from 100 to 30 F. Such low-temperature conditions, which may occur in actual launchings after prolonged periods of coasting, tend to make the pre-pressurizing of the rocket chamber by evaporation of the oxidizer very sluggish. At even lower temperatures, the oxidizer might freeze in the rocket chamber and make ignition impossible.

After these first tests had demonstrated the suitability of simulated high-altitude tests of complete, full-scale liquid-propellant systems, a number of other liquid-propellant engines, again including, in some cases, the entire package—gas generator, pumps, control system, etc.—were investigated.

The propellants of these engines consisted of conventional lox-RP1, lox-ammonia, hypergolic IRFNA-UDMH, and other combinations. (Tests with boron-containing and liquid-hydrogen propellants are in the planning stage.) In these tests, ignition and thrust-termination characteristics, specific impulse, structural integrity after long-duration runs at high altitude, etc., could be determined.

High-altitude tests have demonstrated the performance and functional adequacy of liquid-propellant rockets. In the case of the generally less complex exhaust products that have been encountered with liquid propellants, the theoretical calculations and extrapolations have been somewhat more accurate than those for solid propellants.

Although the ignition tests at high altitudes have proved the reliability of hypergolic-propellant ignition and re-ignition for such rockets as the Bell-Hustler throughout their presently expected operating pressure and temperature ranges, further tests on re-ignition after long-time coasting at high altitude or space environment are required to determine the complete operating limits for various hypergols.



New Solid-Rocket Test Cell for AEDC

With scale indicated by the truck at left, this sketch depicts the new vertical cell being built at the AF's Arnold Engineering Development Center for altitude-testing solid rockets with thrusts up to a half-million pounds.

Excessive Base Heating

Practically all vehicles equipped with rockets that burn for long periods of time have experienced difficulty with excessive base heating. This has sometimes caused the complete loss of vehicles because of fire in the engine compartment or explosion.

Such incidents occurred as far back as the development of the German V-2 and have continued to occur in more recent history with ballistic missiles of various types. For several years, various agencies have conducted model studies of this problem, for example, tests by NASA in connection with the development of the Jupiter ballistic missile for the Army Ballistic Missile Agency. The experimental investigations were greatly intensified after the end of 1957.

Late in 1957 and at the beginning of 1958, tests of such weapon systems as Atlas, Jupiter, Titan, Polaris, and

NASA program-highlights

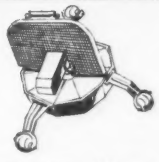
NEXT DECADE IN SPACE

Year 4 to 14 of the Space Age

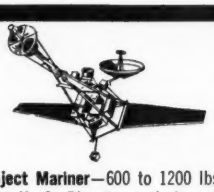
Project Mercury—U. S.'s first manned satellite.

Project Surveyor—First soft landing on moon. Conduct observations from stationary position.

Project Prospector—Soft landing on moon and exploration of area within 50 miles of landing point.

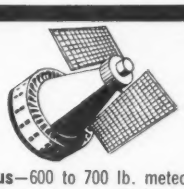


Solar Observatory—350 lb. Large flywheel and extended arms rotate to stabilize. Under construction.

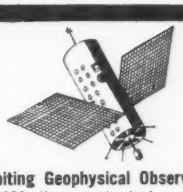


Project Mariner—600 to 1200 lbs. First U. S. Planetary missions to Venus and Mars. Modified craft for hard landings on moon.

Project Voyager—Orbit Mars and Venus and eject instrumented capsule for atmospheric entry and perhaps landing.

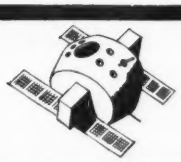


Nimbus—600 to 700 lb. meteorological satellite series. Stabilization system will keep cameras pointed earthward.

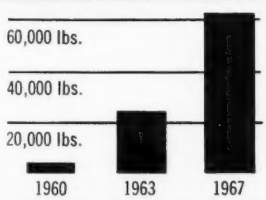


Orbiting Geophysical Observatory—1000 lb. geophysical research satellite designed for a near earth circular polar orbit or an inclined highly elliptical orbit.

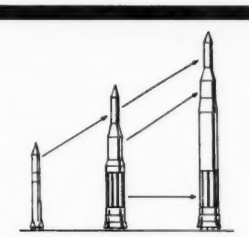
Project Aeros—24-hour stationary weather satellite. Launched in equatorial orbit. Three satellites could permit continuous observation of most of earth's surface.



Orbiting Astronomical Observatory—Standardized, 3500 lb. satellite, for several experiments with different scientific sensors and specialized devices.



Anticipated Growth of NASA Spacecraft in terms of weight of individual near earth satellites.



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NASA Langley Research Center • Hampton, Virginia

NASA Lewis Research Center • Cleveland 35, Ohio

NASA Marshall Space Flight Center • Huntsville, Alabama

NASA Wallops Station • Wallops Island, Virginia

National Aeronautics and Space Administration

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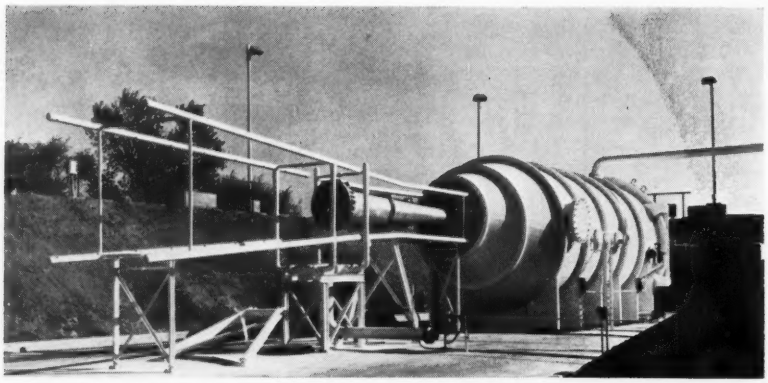


"Backyard" Altitude-Test Facility

Aerojet-General has installed this flexible simulated-altitude test stand for solid motors at its Solid Rocket Plant in Sacramento, Calif. Built by Fluidyne Engineering Corp., the stand will be used by Aerojet for testing motor and nozzle designs.

in several full-scale and model test cells of the AEDC Engine Test Facility.

The objective of these tests was identification of configurations and conditions which caused gases from the main-rocket exhaust and the fuel-rich turbine exhaust to circulate back toward the missile base. It was found that excessive base heating may be experienced either by direct heat transfer or by sustained burning after mixing of the exhaust gases with the oxygen of the atmosphere, with the missile base acting as a flameholder.

By means of systematic probing, the configurations which are safe and those which are unsafe for rocket exhausts were determined using cold-air model rockets as well as hot burning rockets at various test altitudes and flight Mach numbers.

Only at low and medium altitudes is the danger of sustained burning in the base region likely. At high altitudes, because of the absence of sufficient oxygen, the danger no longer exists. In other cases, mainly that of ring cluster rockets, a different type of exhaust recirculation which causes base overheating can occur, particularly at the high altitudes extending into space.

The testing techniques that have been developed and employed in numerous tests at the AEDC were found to give adequate results and correlation with flight tests.

Data from these various tests, as well as the results of theoretical and experimental studies carried out during this same period, provided a better understanding of the phenomena that occur at the base of a missile. The flow patterns to be expected for a given missile at various trajectory conditions can now be predicted. However, high-altitude testing is still required to obtain accurate heat-flux, hinge-moment, and pressure data.

The large wind tunnels and test cells of AEDC, even though not originally designed for experiments with burning rockets, are well suited to provide the atmospheric and space environment required for rocket tests at high altitudes. In the large wind tunnels, various subsonic and supersonic airflows and scavenging systems are available for study of flow phenomena in the base region of model rockets, including the interaction between rocket exhausts and external flow.

In the high-altitude test cells, on the other hand, the available exhauster capacity can be readily used to simulate a high-altitude environment without external flow for full-scale rockets.

In order to augment the exhauster capacity of the basic AEDC plant, and thus to improve the altitude limit of tests, various types of ejector diffusers have been systematically investigated in scale-model tests and have been subsequently applied to full-scale tests.

A typical scheme now in general use at AEDC consists of the test rocket installed in the altitude chamber with the rocket exhaust providing an auxiliary pressure boost during rocket operation and an auxiliary ejector driven by air or steam providing proper simulation of ignition and burnout conditions.

This test scheme is basically the same one developed for the first full-scale tests at AEDC in 1958. Since then, systematic model testing has succeeded in continuously improving the performance of the arrangement.

The measuring and recording of rocket parameters such as thrust, pressure, temperature, etc., also pose tremendous problems, even for the controlled conditions of a test facility. One main problem area in rocket testing is centered around the highly transient conditions which occur during ignition and burnout. Realizing, furthermore, that thrust accuracies of a fraction of a per cent are required, it is obvious that special instrumentation is needed to meet these requirements.

Elaborate instrumentation, based on precision wind-tunnel testing techniques, multi-redundant arrangements of pickups and measuring circuits, and precise and repeated calibration techniques have made it possible to come close to this goal in the AEDC cells.

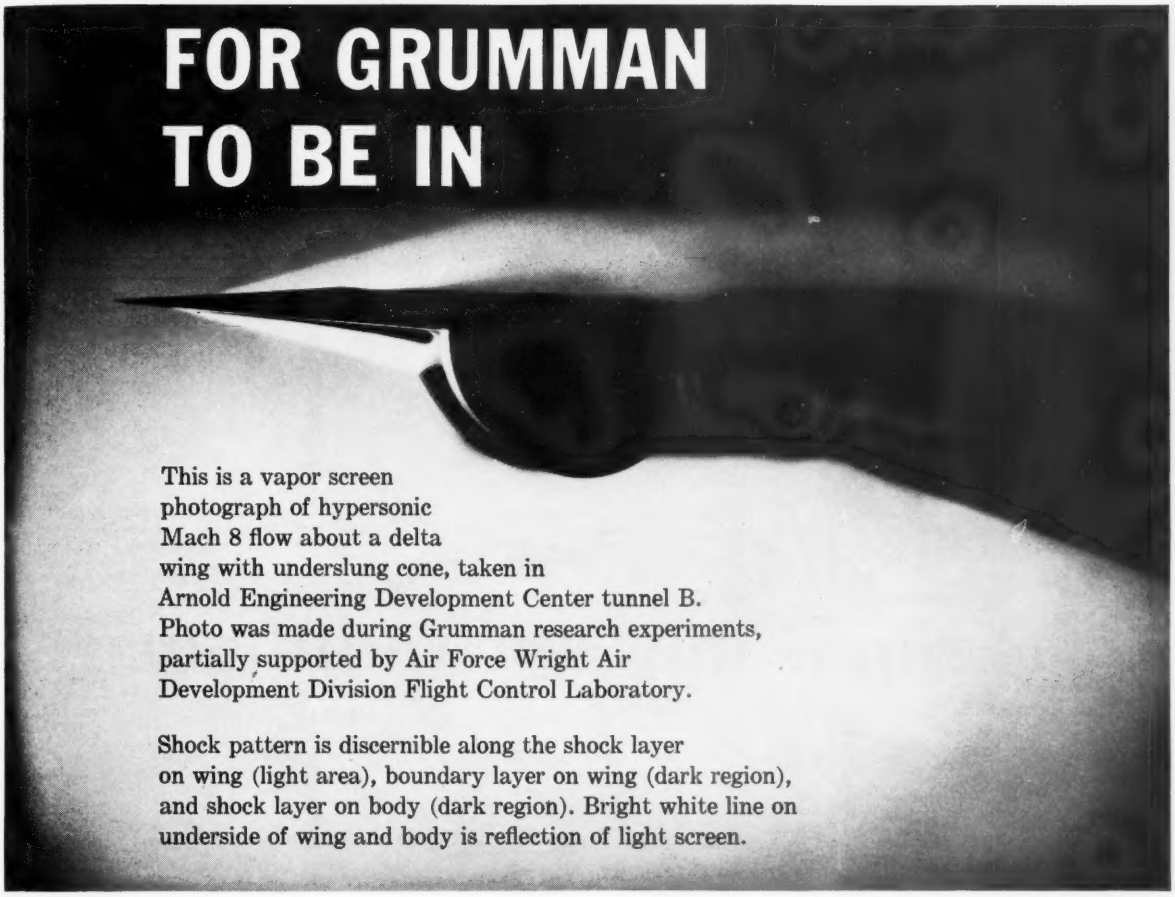
Lately, an especially difficult instrumentation problem occurred when it became apparent that even a solid-propellant rocket will continue to produce very small amounts of thrust after shutdown (less than $^1/_{20}$ per cent of maximum thrust) for periods of 2 to 3 min due to smoldering burning of internal case liners, remnants of propellants, or outgassing of internal walls. These very small thrust values must be measured, since they might cause collision of the empty rocket case with payloads.

Simulated high-altitude testing of rocket engines offers a new means of determining and solving before an actual launching some of the problems connected with high-altitude operation of rockets in the easily controlled test conditions of a laboratory. Tests conducted to date have already shown, in numerous cases, that deficiencies of rocket-engine systems can be detected before launching, corrections can be applied, and, consequently, the final launching of actual full-scale missiles and space vehicles can be made more reliable. ♦♦

IGY World Data Center Reports

Data and preliminary results from IGY projects are being issued regularly by the IGY World Data Center in two series of reports, one concerned with general information and one with rocket and satellite studies. Each report costs $1.00, postage prepaid. Standing orders may be placed for the series, which thus far includes six general reports and thirteen on rocket and satellite studies. Orders should be directed to the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Ave. N.W., Washington 25, D.C.

NOTHING IS TOO FAR OUT.... FOR GRUMMAN TO BE IN



This is a vapor screen photograph of hypersonic Mach 8 flow about a delta wing with underslung cone, taken in Arnold Engineering Development Center tunnel B. Photo was made during Grumman research experiments, partially supported by Air Force Wright Air Development Division Flight Control Laboratory.

Shock pattern is discernible along the shock layer on wing (light area), boundary layer on wing (dark region), and shock layer on body (dark region). Bright white line on underside of wing and body is reflection of light screen.

This photo characterizes the work Grumman is doing in hypersonic aerodynamics. Other efforts at Grumman include continuing design and development work on orbiting observatories, interplanetary communication systems, re-entry vehicles and reconnaissance satellites, to name a few.

Most important: Grumman has the "people capability" to transform advanced ideas to reality. So . . . if you have a problem that's far out . . . call Grumman in.

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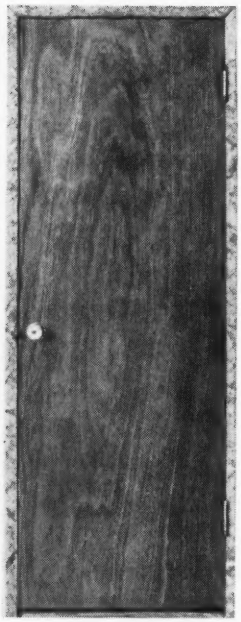
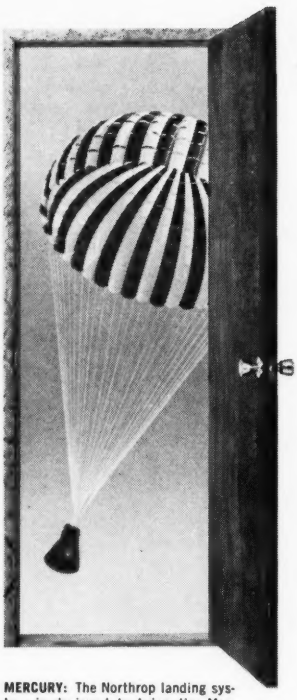
POLARIS: Northrop's Datico checks out Polaris at all levels of maintenance and operation.

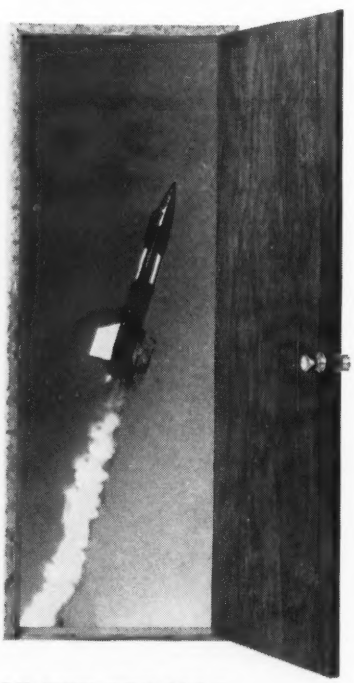


SKYBOLT: Guidance and navigation systems are being developed by Northrop for this new and highly secret air-launched ballistic missile.

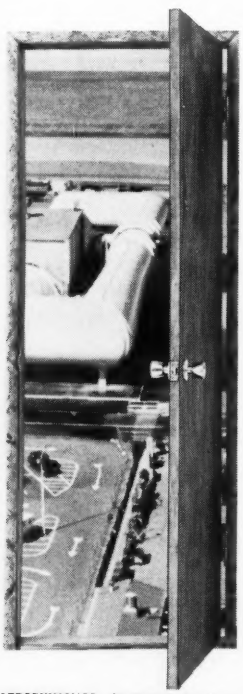


MERCURY: The Northrop landing system is designed to bring the Mercury astronaut down safely.

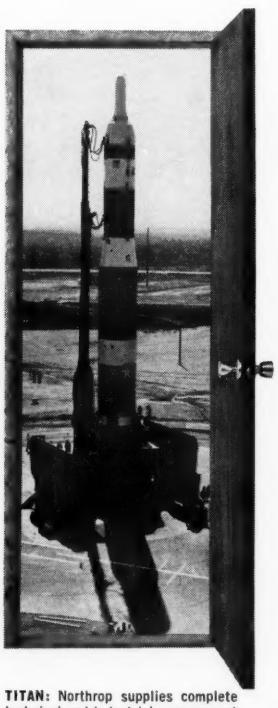
Northrop is now active in more



X-15: Northrop produces Q-Ball, the flight angle sensor for safe re-entry of X-15 and other aerospace vehicles.



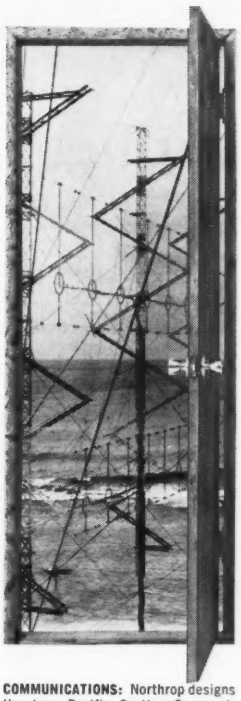
AERODYNAMICS: Northrop's Laminar Flow Control technique is designed to greatly increase aircraft range, flexibility, cargo and passenger capacity.



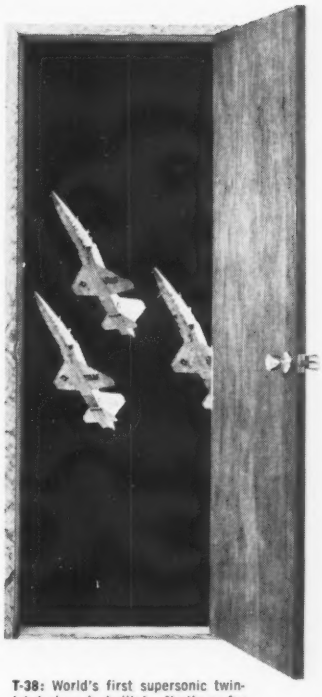
TITAN: Northrop supplies complete technical and industrial management to activate the T-2 Titan missile base.

Northrop Corporation, Beverly Hills, California • Divisions: Norair, Nortronics, Radioplane, Northrop International

HAWK: Northrop produces airframe components, ground handling and launching equipment for this air defense missile.



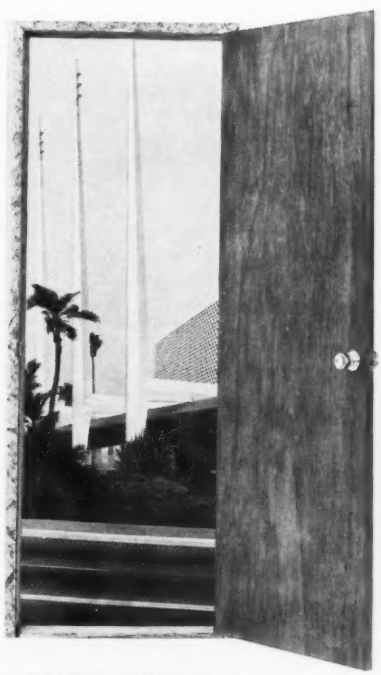
COMMUNICATIONS: Northrop designs the trans-Pacific Scatter Communications Network and other worldwide communication systems for U.S. and free world governments.



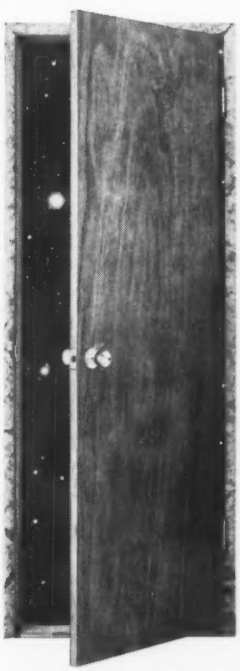
T-38: World's first supersonic twin-jet trainer is built by Northrop for the United States Air Force.

than 70 important programs

TARGET MISSILES: Northrop has produced more than 50,000 electronically-controlled aerial targets, and surveillance drones.



COMMERCIAL METAL PRODUCTS: Northrop produces aluminum architectural shapes for many important industrial and commercial buildings.



SPACE RESEARCH: Northrop's accelerated space research programs reach into such advanced areas as maneuverability, rendezvous, space vehicle maintenance, space probes, and the survival of men in space.

Subsidiaries: Page Communications Engineers, Inc., Acme Metal Molding Company.

Careers in astronautics

By Irving Michelson, *Illinois Institute of Technology*

IN FORMULATING its detailed program of second-generation space vehicles, the NASA is giving to the astronautical experts in industry the somewhat unusual and enviable opportunity to write their own ticket. Following its series of industry briefings, NASA is scheduled this month to assign to two or three major contractors the responsibility of setting their own realistic goals for the spacecraft it hopes to develop within the next few years. In addition, the space scientists and engineers are asked to designate the areas requiring long lead times in research, and to provide cost estimates for the Project Apollo manned spacecraft system. When these studies are completed, it is expected that NASA will select prime contractors to receive the largest portion of its total budget for forthcoming programs (nearly one quarter of a billion dollars for Fiscal 1961). The outline given for Apollo emphasized design considerations for a three-man crew of astronauts working in shirt-sleeve environment and adequately protected from harmful radiations. Bio-medical and bio-instrumentation problems loom large, along with tough survival requirements and safe return and re-entry conditions. In other programs, the orbiting astronomical observatory and another geophysical one call for launchings by early 1963, to contain modular half-ton flight packages, the subsystem areas being left open at this time. It will be interesting to see how our space designers will respond to this challenge to define the mission then design and fly the vehicle, and to do so to meet a deadline. Here is a real opportunity for those in the industry, whether critical of progress heretofore or not, to "put up."

* * *

An important tool for experimental studies of re-entry has recently been put into operation at Boeing's Seattle plant which should assume major importance in present and future space research. A hypervelocity wind tunnel, operating on the "hotshot" principle of electrical arc discharge, it is designed to furnish data in the speed range from Mach 10 to 27, simulating speeds of satellite launching, as well as severe thermal conditions. Immediate applications are in Boeing's Dynasoar program, to delineate the re-entry "corridor," and for Minuteman, where designers need data on heating, stability, and drag. The very limited number of research facilities with such capabilities, coupled with their complexity and high cost, provide strong reason to expect this newest "hotshot" to be very heavily used in the next few years. Its operation and data collection and processing will occupy many engineers, technicians, and mathematicians in the Seattle area, probably on an around-the-clock basis.

* * *

Technicians are particularly important to the successful operation of all such facilities, and we find it more than a little disturbing to be told how poorly our laboratories in this country are being provided with this type of talent. A delegation of American engineers, members of the Engineers Joint Council group visiting Russia last summer, has revealed that of the 15,000 graduates of our own technical schools last year not more than 1000 are of the quality being produced in the Soviet Union (where the technician graduates each year are estimated to number fully 250,000).

There is no doubt that better-trained technicians would be of great importance in our programs, going far toward solving the problem of the shortage of engineers and scientists, since in the absence of competent technicians, professional persons are usually assigned to sub-professional tasks. This waste of manpower is all the more unfortunate as it hinders the much needed professional advancement and heightened level of competence of many men who wish to make greater contributions to our astronautical progress.

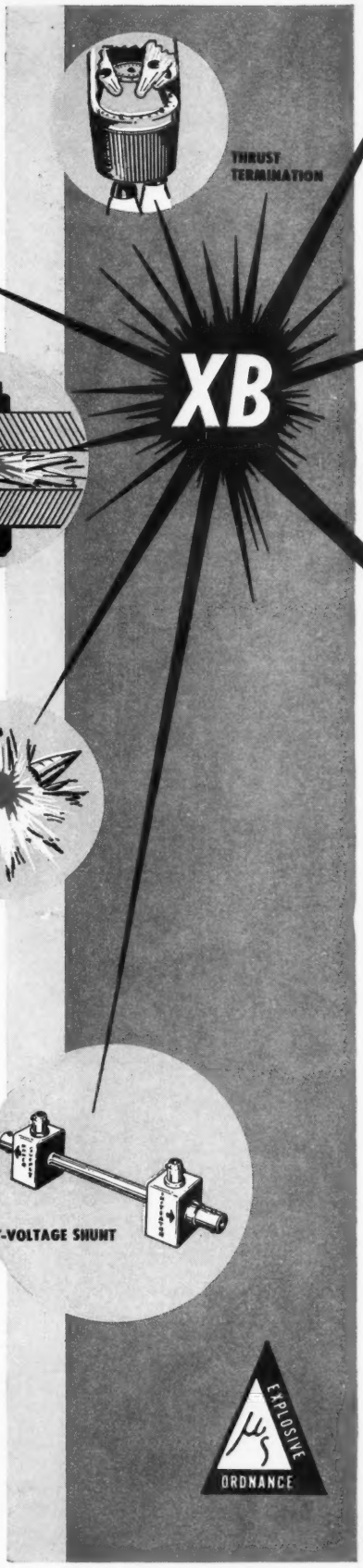
* * *

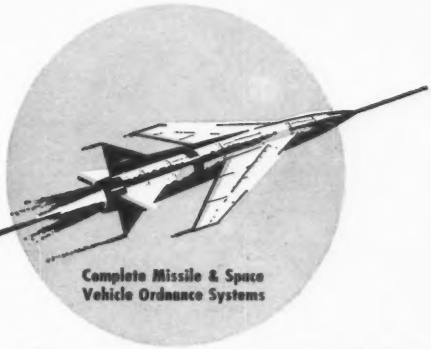
One of the newer areas into which engineers and scientists should be moving is the field of nuclear-rocket propulsion. When we read recently of the merger of AEC and NASA efforts in this area, therefore, it was striking to learn that the headquarters for this effort in Germantown, Maryland, will be staffed by about only 15 individuals from both of these agencies as well as the Air Force. Considering the importance of Rover, Snap-8, and other advanced nuclear-rocket propulsion programs, we wonder to what extent our manpower "shortages" are penalizing our efforts.

A great stimulus has been provided by astronautics for research in allied fields, and we notice an increasing emphasis, not only in astrophysics and geophysics, but also in oceanography and the earth sciences broadly. It is especially gratifying to learn, so soon after the Research Council warned publicly of the serious lag in this country's research in oceanography, that a major industrial group has made a strong move to enter the field. The Defense Products Div. of General Motors has announced its plan for an extensive program dealing with underwater instrumentation in its newly acquired Santa Barbara facility, lately acquired from Curtiss-Wright. This should bring a freshness and a vitality into a long-neglected scientific field, and a new challenge to designers who have not dealt with oceanographic research problems in the past.

There may be a big field for space lawyers, but after their recent troubles in Copenhagen, we expect many of them to seek cover in other areas than space law. At the 11th Annual International Astronautical Congress held there, there was so much sparring and bickering over organizational and procedural questions that little real progress or much optimism could be found for future progress. This country's chief rival for space supremacy either declined or seriously limited its participation in such agencies as the International Institute of Space Law, the Committee for Space Research of the International Council of Scientific Unions, and the International Astronautics Academy. It is certainly unfortunate that world politics finds its way into these groups in such a deleterious manner, hampering international accord and even placing obstacles for the free exchange of technical information.

For specific career opportunities this month, see Third Cover, pp. 1, 4-5, 7, 9, 13, 15, 19, 41, 49, 50, 51, 52, 55, 57, 60, 61, 67, 77, 78, 84.





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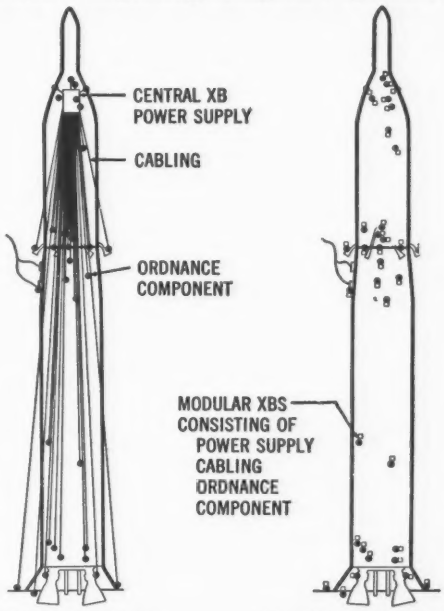

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LUNAR PROBE

The moon — lacking an erosive atmosphere — may hold the key to the history of the solar system. Because of this lack of atmosphere, oceans, and wind, lunar explorations may help solve fundamental, universal questions.

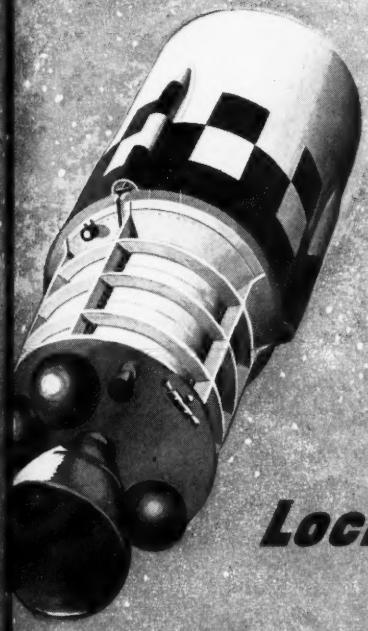
Logically, the moon will be the first objective in the exploration of space. Initially the moon itself will be photographed and instrumented; then manned observation stations will be established for astronomical and meteorological purposes. In time, the moon will serve as an intermediate station enroute to other planets — step by step into infinite space.

The National Aeronautics and Space Administration's Lunar Program will utilize Lockheed's AGENA B satellite to play a significant part in forthcoming lunar explorations — as well as a host of other scientific space missions. The NASA lunar launch in 1961-62 will utilize the highly reliable Lockheed AGENA as second stage to carry the RANGER spacecraft. The AGENA will provide the extremely critical guidance and controls necessary to place the RANGER on the required lunar impact trajectory.

The lunar probe application demonstrates the versatility, reliability and success of the AGENA vehicle in Lockheed's satellite and spacecraft programs. Developed for the Air Force for use in the DISCOVERER program, the AGENA is utilized in the MIDAS missile defense alarm system and the SAMOS surveillance satellite system. Noted for a record of outstanding accomplishments, the AGENA is credited with being the first to be placed on a polar orbit; first to achieve a precise, predicted and nearly circular orbit; first to attain attitude control on orbit; first to eject a reentry capsule which was successfully recovered. The AGENA can be modified for a variety of space missions such as navigation, geophysical investigations, long-range communications and deep space probes.

Lockheed's capability in satellites and spacecraft, manifested by such an achievement as the AGENA, encompasses the entire field. It includes current and long-range programs such as interplanetary probes, global and space communication systems, and manned space travel.

Engineers and Scientists: The accomplishment of such programs offers challenging opportunities to engineers and scientists in the research, design, development, test and operation phases of these programs. If you are experienced in work related to any of the above areas, you are invited to write: Research and Development Staff, Dept. L-29, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required.



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New Standards

(CONTINUED FROM PAGE 25)

tenance, adjustment, and repair of the instruments.

Illustrations of pyramidal systems of laboratories are now numerous. The Air Force has been moving rapidly toward a single, integrated calibration system headed by the USAF Calibration Laboratory at Dayton Air Force Depot. At the next echelon, the "AMA-level" laboratories—16 in number—are located at various Air Materiel Areas and certain AF Depots. At the next lower echelon are the standards laboratories that will be located at AF base calibration and maintenance shops. Many of these laboratories are now operational, and about 160 are planned for activation within the next year or two.

A number of large corporations which operate manufacturing plants or research and development laboratories in different locations have developed or are in the process of developing similar systems of standards laboratories, each system being headed by a central corporate standards laboratory.

These systems of standards laboratories serve a very useful function in providing the many different units of large organizations with the needed measurement capabilities without the waste and inefficiency that would undoubtedly occur if the individual units with personnel inexperienced in standards should each set up its own standards program. Furthermore, under such circumstances, it would be impossible for NBS to provide even token calibration services for the great number of standards laboratories now required by science and industry.

Systems of standards laboratories are subject to the major disadvantage that there may be a loss of precision at each stage of calibration. There is a corresponding loss of accuracy unless the precision of measurement exceeds the absolute accuracy of the standard. In everyday calibration this loss seldom amounts to less than a factor of two and may be as much as a whole order of magnitude. Exceptions to this attenuation occur with the standards of a few quantities, such as resistance, where intercomparisons can be made with much greater precision than the absolute accuracy of the standard.

Some standards, such as the standard of mass, are available at NBS of such accuracy that even after going through several successive echelons of calibrations they are still sufficiently accurate for the large majority of practical purposes. The six successive intercomparisons that intervene between the international prototype at Sevres and the 50-lb weight that serves our states and many industrial organizations as a standard for large weighing operations result in a reduction in accuracy from 1 part in 100 million to 1 part in 200,000.

With many other standards, however, the requirements for accuracy at the operating level are such that no attenuation is permissible. The highest possible accuracy is needed at the working level, so it is not possible to employ a hierarchy of standards but only a national standard and a working standard for end-use purposes. This situation now occurs with measurements of time, frequency, and force, and is coming to be true of length measurements. With still other standards there are advantages to be gained in avoiding the use of a calibration chain.

The Bureau employs three means of providing standards when little or no attenuation is permissible. One way is by setting up a central facility at the Bureau with sufficient capacity to perform all calibrations that are needed in terms of a single standard of the highest accuracy practical. This procedure is likely to be inconvenient and time-consuming, but no other procedure seems practical for the adequate calibration of instruments, such as those used for the measurement of large forces.

A diametrically opposite way is to establish standards in terms of certain atomic or molecular properties which can be realized in any laboratory equipped for the purpose. Molecular transitions, such as melting, boiling, or changes from one solid phase to another, provide the basis for standards of temperature, pressure, and luminance. Transitions in atoms from one energy level to another give rise to electromagnetic radiations which, in the visible spectrum, provide the wavelength standard of length and, in the radio spectrum, the standard of frequency.

A third means of making standards available with the minimum loss of accuracy is by radio broadcasting, as is now done for standards of time and frequency.

Let's look at several illustrations of these three methods of providing standards to meet present-day needs.

Increased accuracy is urgently needed for the measurement of the thrust of rocket engines in connection with missile and satellite programs. The basic facility now in use at NBS for the calibration of thrust-measuring devices is a 110,000-lb deadweight machine installed more than 30 years ago. Within its range this machine affords an accuracy of 0.02 per cent, which is adequate for most present needs. But rocket engines are being

built with thrusts up to a million pounds, and even larger engines are planned. For calibrations above 110,000 lb, indirect means are employed and the accuracy in the range of 1,000,000 lb is only about 0.4 per cent, whereas at least 0.1 per cent is needed.

One missile contractor finds that much of the uncertainty in the value for the thrust of a rocket engine resides in the uncertainty in the calibration of the load cells used for force measurement. Hence, a number of rocket engines must be tested to determine the thrust with the requisite accuracy. An increase in the accuracy of calibration from the present 0.4 to 0.1 or 0.2 per cent would bring about a very substantial saving by reducing the number of rocket engines that have to be tested.

Rocket engines represent by no means the only application calling for the measurement of large forces. Load cells for large-capacity scales likewise require calibration by means of dead weights. An accuracy of 0.05 per cent is currently needed for some scales, and the need for even greater accuracy can be foreseen.

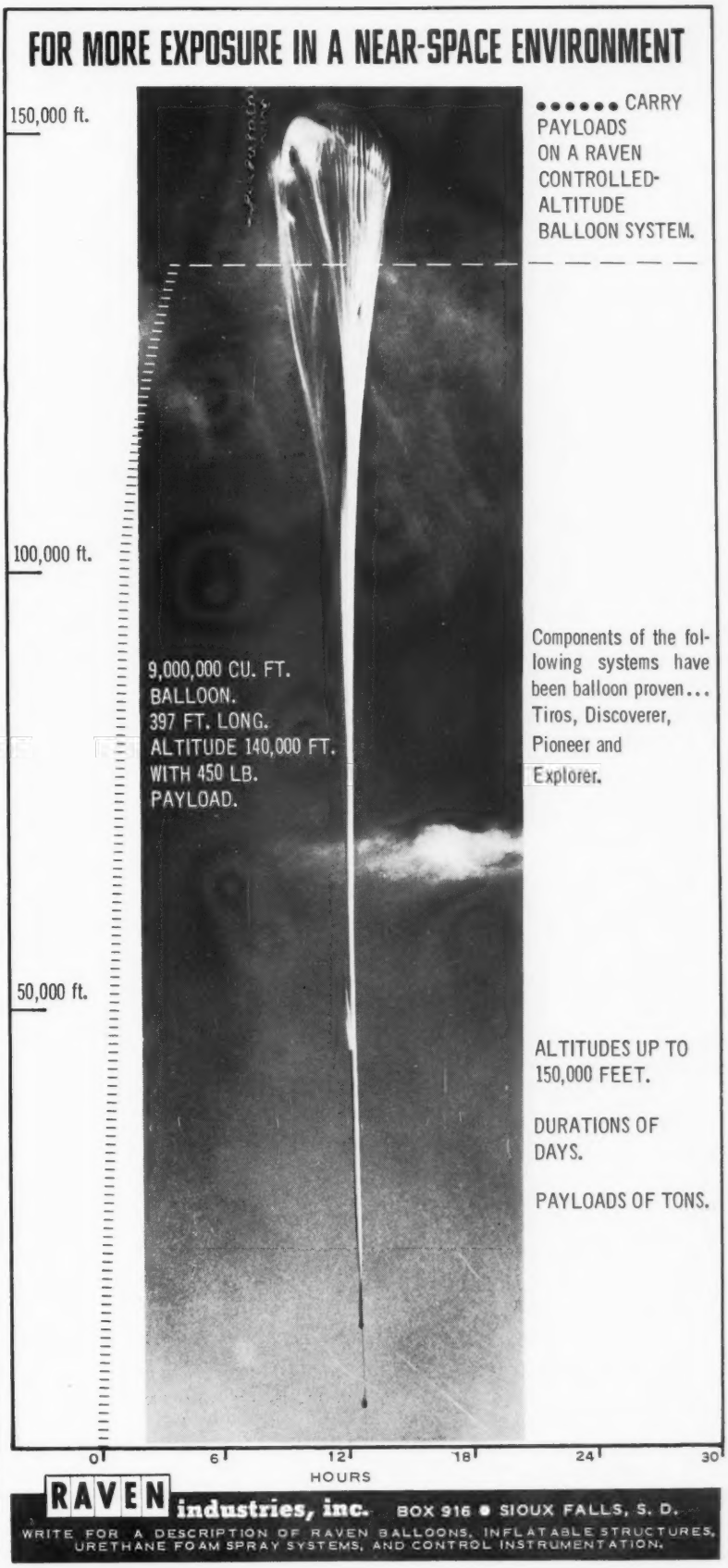
To meet these and other needs for the measurement of large forces, the Bureau has planned three new deadweight machines with capacities of 100,000, 300,000, and 1,000,000 lb, respectively, and with an accuracy of at least 0.005 per cent. These machines have required a special building, which has become one of the first units to be erected in the Bureau's relocation at Gaithersburg, Md.

The measurement of force by deadweight devices requires a knowledge of the masses of the weights and the constant of gravitation, g, at the point of measurement. Relative measurements of g can be made to about 1 part in 10^8 but the absolute value is known with an accuracy of only about 2 or 3 parts in 10^6. The Bureau is now engaged in a project for the redetermination of g with a higher degree of accuracy; this may take several years.

When this redetermination is made, it will affect the absolute values for standards of pressure and electrical quantities as well as standards of force, since the constant of gravitation enters into the derivation of these and still other quantities.

While the Bureau's deadweight machine for measuring large forces would be too large and expensive for most other laboratories to duplicate, this is not the case for some of the standards based on molecular and atomic properties.

The transitions between phases—or, more particularly, the conditions under which two or more phases are in equilibrium—serve to define pressure and temperature scales, and are analogous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to the changes in energy levels of atoms, which provide standards of frequency and length. The thermodynamic temperature scale is defined by fixing the triple point of water (the point at which ice, water, and water vapor are in equilibrium) as 273.16 K.

The International Temperature Scale is based on six reproducible temperatures (defined fixed points) to which numerical values are assigned, and on specified formulas for the relations between temperature and the indications of instruments calibrated near these temperatures. These temperatures are established by the following sytems in equilibrium. The pressure, except for the triple point of water, is one standard atmosphere.

Liquid oxygen and its vapor (oxygen point)	−182.97 C
Ice, liquid water, and vapor (triple point of water)..	+0.01
Liquid water and its vapor (steam point)	100.0
Liquid sulfur and its vapor (sulfur point)	444.6
Solid and liquid silver (silver point)	960.8
Solid and liquid gold (gold point)	1063.0

On the basis of these fixed thermometric points it is possible for a laboratory to maintain its own temperature scale and thereby to be independent of any national or international standards laboratory. In practice, however, it is more convenient for most laboratories to use as standards platinum resistance thermometers, thermocouples, and even liquid-in-glass thermometers which have been calibrated by the Bureau. The two points most difficult to maintain accurately are the steam point and the sulfur point. Both are markedly affected by fluctuations in atmospheric pressure, and in addition the sulfur boiling equipment must be kept in operation for a period of several days to insure the attainment of equilibrium between phases of the sulfur.

Two developments at the Bureau will materially improve this situation. One is the preparation and issuing of a standard sample of pure zinc, which has a solidification temperature of 419.50 C. This temperature is close enough to the sulfur point to replace it for calibration purposes. The zinc point is relatively easy to attain and is little affected by changes in barometric pressure.

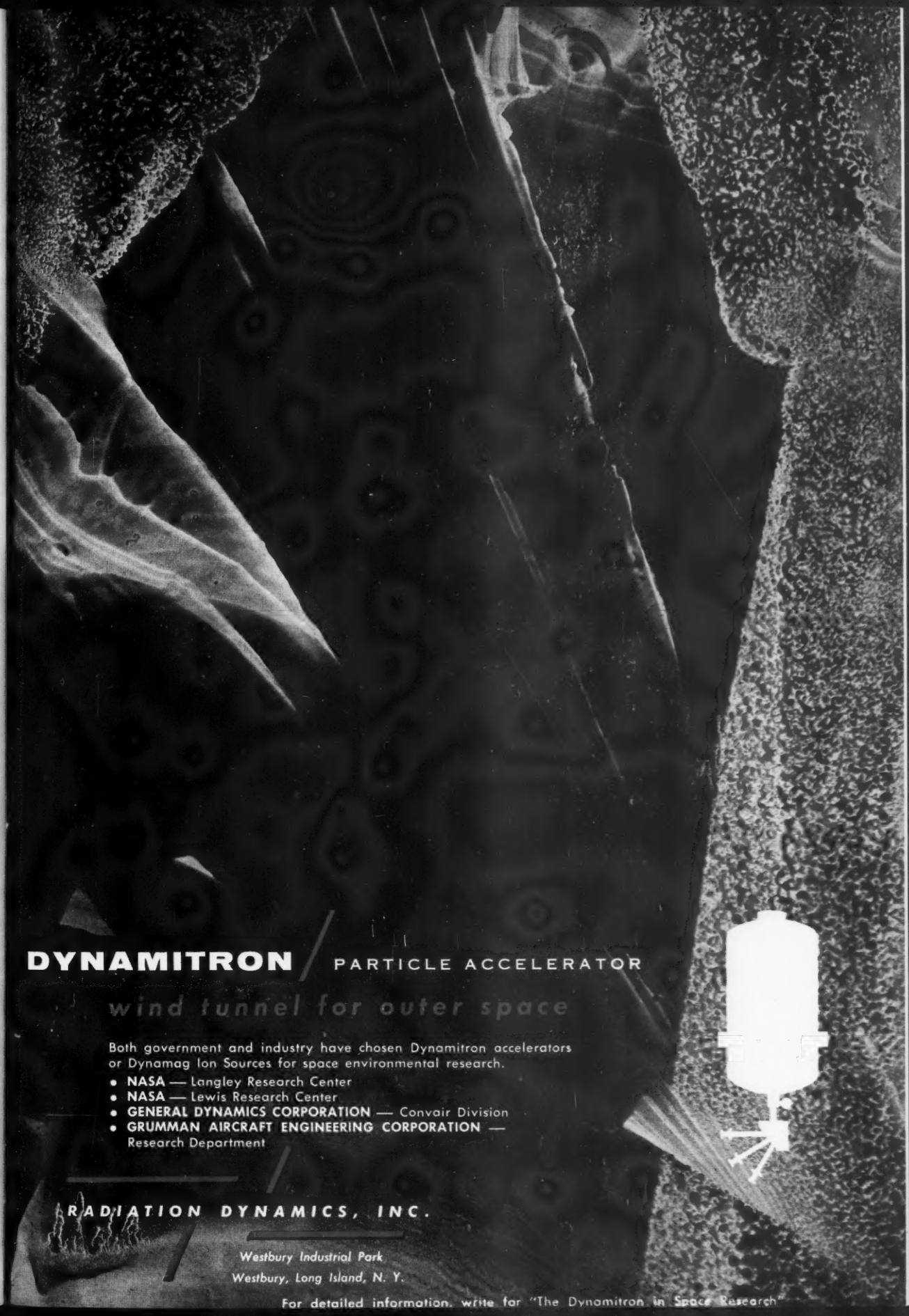
The other development is the preparation of thermometric cells employing pure organic substances to serve as convenient reference temperatures up to and above the steam point. The substances available include phenol, naphthalene, phthalic anhydride, and benzoic acid. They cover the range from about 41 to 122 C. The cells are made by placing the substances in evacuated glass tubes with re-entrant cavities. These cavities allow the thermometer being calibrated to be surrounded by the reference material, which is melted and allowed to solidify partially.

In the field of pressure measurements, the Bureau is undertaking the accurate determination of points to fix the pressure scale. In some instances, the Bureau's work will be the redetermination of points previously established by Bridgeman and other workers. In other instances, new points will be investigated and characterized. Some of these points involve a change from liquid to solid with increasing pressure. At higher pressures, however, suitable liquids are not available, and it is necessary to employ transitions from one solid phase to another, detecting the change by the accompanying change in volume, electrical conductivity, or some other property.

Closely related to the standard of temperature is the standard of luminance, a black body at the freezing point of platinum, which, by definition, has a luminance of 60 candelas per square centimeter.

Standards based on atomic radiation are capable of far greater accuracy than ones based on physical prototypes. They can be realized independently in any well-equipped laboratory without excessive expense or difficulty. Electromagnetic radiation results from the change of an atom under excitation from one energy level to another. In principle, any atomic radiation is a potential standard of length and frequency. In practice, radiation in the visible portion of the electromagnetic spectrum affords a practical standard of length; radiation in the ultrahigh frequency radio range, a standard of frequency.

For an isolated atom the energy difference between two energy states is invariant, and consequently the emitted or absorbed frequency is likewise invariant. In undertaking to obtain a single, exact frequency from any practical source, however, two difficulties may be encountered. The first is in obtaining a single atomic species, free from isotopes that give slightly different frequencies. For this reason the original work by Michaelson and others on the wavelength standard of length was done with light from a cadmium source, cadmium being the only element suitable for a lamp which occurs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in nature without isotopes. Now single atomic species can be obtained by fractionation of the natural isotopes or by nuclear reactions, as, for example, the formation of mercury 198 from gold.

A second source of difficulty lies in the Doppler broadening of the electromagnetic spectral line by the thermal agitation of the molecules. This effect can be minimized by lowering the temperature of the emitting atoms to reduce the magnitude of the thermal agitation, or by employing the atoms in a beam at low pressure so that they are all moving in one direction without significant motion as they are observed at right angles to the beam. There are additional factors associated with the apparatus and the conditions of observation that have slight effects on the frequency, and hence must be taken into account for work of the highest precision.

We have already seen the International Committee on Weights and Measures, which met this past year, adopting a wavelength standard of length to replace the platinum-iridium meter at Sevres, up until then the international standard of length. The basic reason for the change is that the fiducial lines on the prototype meter cannot be read with an accuracy greater than about 2 parts in 10^7, whereas there are practical needs for measurements with an accuracy of a few parts in 10^8 or even 10^9. A further consideration is the fact that length measurements of the highest precision are almost invariably made by means of the interferometer in terms of wavelengths.

Sources for Wavelength Standard

The three sources under consideration for the wavelength standard were the red line of cadmium, the green line of mercury 198, and the orange line of krypton 86. The last was adopted, as seemed likely, and at the present time, the meter has been defined as equal to 1,650,763.73 vacuum wavelengths of the radiation corresponding to the transition between the energy levels 2 p_{10} and 5 d_5 of the krypton 86 atom, the corresponding value of the wavelength being $6057.8021_1 \times 10^{10}$ meter. Although the krypton source has certain advantages as an absolute standard, the greater convenience and facility of operation of the mercury source will undoubtedly make it preferable for many practical applications.

The first radio waves used as frequency signals were those associated with the inversion of the ammonia molecule, in which the nitrogen atom reverses its position with respect to the plane of the three hydrogen atoms. At present, very successful use is being made of a transition in the cesium atom, which has a frequency near 9200 mc per sec corresponding to a wavelength of about 3 cm. The cesium is used in an atomic beam, and the equipment has been developed to a point at which it has a precision of 5 to 8 parts in 10^{12}—the highest precision that has thus far been attained in any physical measurement. Even greater promise is shown by the thallium beam, which, because of the higher atomic weight of the thallium and for other reasons, appears to be capable of even higher precision than the cesium beam as a source of frequency.

To make the national standards of frequency and time readily available, broadcasts are made continuously from three stations: WWV at Beltsville, Md.; WWVH at Maui, Hawaii; and KK2XEI, an experimental 60-kc station at Boulder, Colo. These broadcasts are widely used for many purposes. Some of the applications—such as the use of the 600-cycle frequency for the control of the 60-cycle generators in powerplants, or the musical note at 440 cycles for musical instruments, or the announcement of Eastern Standard time over WWV—do not require extremely high accuracy. However, research activities and certain operations in connection with satellites and missiles require the highest accuracy that can be attained, and numerous improvements have been made in the electronic equipment of WWV to increase the reliability and stability of the signals that are transmitted.

The accuracy of signals as broadcast by WWV and WWVH at 2.5 to 25 mc has now reached a point at which differences in path resulting from variations in height of the reflecting layers of the ionosphere and distortion of the signal in transmission have become quite significant, and further increase in accuracy at the transmitter would be of little advantage to the user. For this reason the 60-cycle, experimental broadcast by KK2XEI has been instituted to provide users with a service that will be more accurate than that obtained from WWV. Theoretical and experimental studies have shown that at very low frequency the received frequency may be a thousand times more precise than at high frequency. As a result of these studies, a method is under development for modulation of time signal very-low-frequency carriers, so that the signals received from the station will permit frequency and time-interval calibrations to be made to a precision and accuracy far greater than is now possible at high frequency.

The increasing need for the highest attainable precision in many measurements will undoubtedly encourage laboratories to establish atomic and molecular standards for calibrating lower-echelon standards or even for use in monitoring the production of very critical items. This situation, however, will not make individual laboratories completely independent of the national standards laboratory, because there will still be need for checks to insure that the atomic and molecular standards are correctly maintained and used. The effects of extraneous factors on these standards are usually second-order effects. Nevertheless, they must be taken into account when the highest possible degree of accuracy is sought..

In conclusion, the unprecedented scientific and technical advances of the Space Age have demanded measurements of greatly increased accuracy over wide and often hitherto unexplored ranges of properties. These demands have suddenly brought into being large systems of reference and working standards laboratories in both industry and government. These laboratories will continue to derive some of their standards by intercomparison with prototypes maintained by the National Bureau of Standards, but to an increasing extent they will utilize standards based on invariant constants and properties of atoms and molecules.

♦♦

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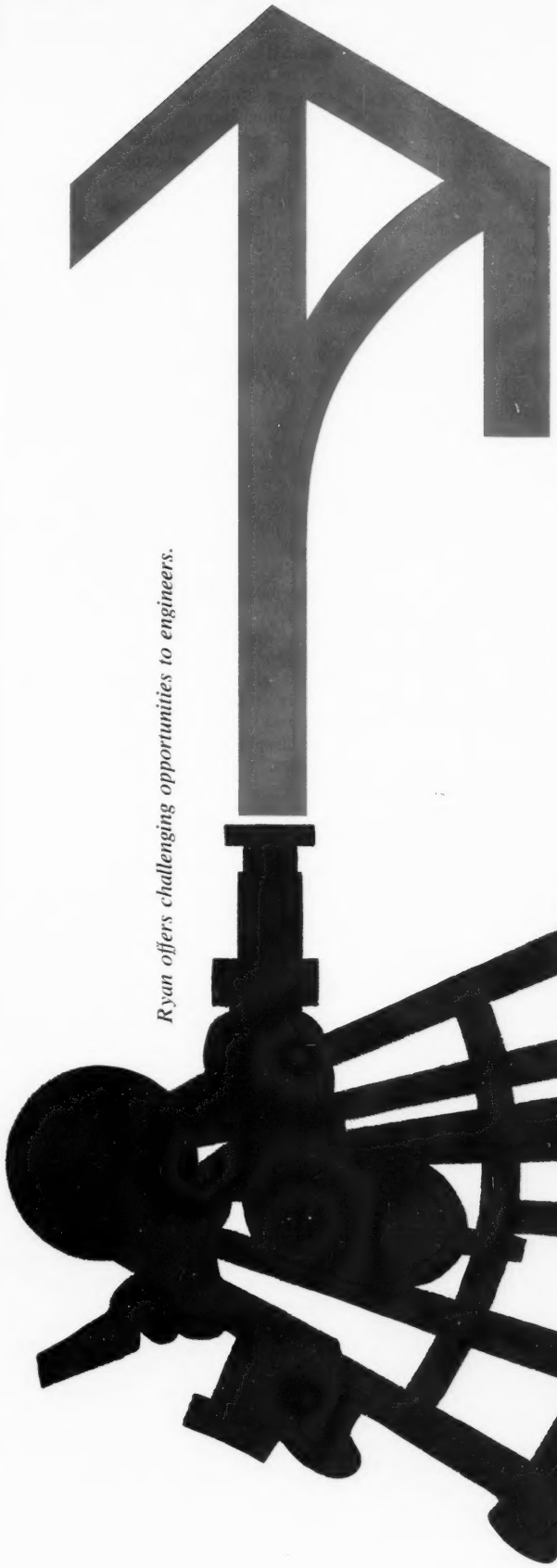

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Self-Erecting Space Lab

(CONTINUED FROM PAGE 23)

1 per cent of the weight of the station.

3. Number of people.....a minimum of 2
4. Food, water, supplies.....60 days
5. Artificial gravity..0 to 0.5g
6. Solar powerplant, fluid cycle.....8 kw
7. Pressures:
   (a) Oxygen partial pressure .....3.1 psi
   (b) Total pressure..... 7.0 psi
8. Atmosphere (to coordinate work) ARDC–1959

After considering various configuration possibilities–such as cylinder, sphere, torus, and disk–we have selected two for serious study, the cylinder and the torus. Studies at the NASA Langley Research Center have shown that the cylinder, which would constitute an ideal configuration for a space laboratory without artificial gravity, has a major shortcoming if artificial gravity is introduced by rotation about a major axis of inertia. Since the two major axes are approximately equal, the station is not safe if the stabilization system cuts out. The studies show that internal weight shifts, such as would be caused by personnel movements, might cause the station to undergo large amplitude wobbling motions leading to loss of solar power, thermal balance upsets, etc. Shapes such as the disk or torus do not have this drawback.

As a result, the major part of our research effort to date has been concerned with the interrupted torus, and that form is the basis of our discussion here. Also, because of the aeroelastic and structural problems involved in launching a complete space station including powerplant on a slender rocket, attention has been focused on erectable designs which can be packaged in the slender form. The inflatable torus is one form of erectable design which is attractive for the following reasons:

(1) It provides a compact package in combination with the parabolic solar collector under study at the Langley Research Center.
(2) Stabilization of a spinning torus is fairly simple since the spin axis is aligned with the major axis of inertia.
(3) The spinning torus serves to introduce uniform gravity throughout the living section.
(4) For a given station weight the large diameter provides artificial gravity at low rpm to minimize gyro torques on inner-ear fluid with accompanying disorientation.

A model of the erectable torus design has been constructed. Before describing the model, let me emphasize that although a particular design concept has been selected to point up the research areas of interest, NASA is not involved in the development of any particular configuration. The objective is instead to conduct general research in these areas so that basic information can eventually be supplied for the design of manned orbiting laboratories.

The upper half of the model, shown on page 23, contains the entire station, including living quarters and solar powerplant. The lower conical section represents the final stage of the rocket launching system. Arriving in orbit, it would at first be pointed at the sun by the launcher stabilization system. Then the nose cone would be ejected, allowing the two semicylindrical powerplant radiators to come open. This exposes to view the cylindrical container between the radiators that houses inflation bottles and the life-support system, such as air conditioner, etc. The center of this container includes a zone in which zero-g experiments might be conducted even while the station rotates.

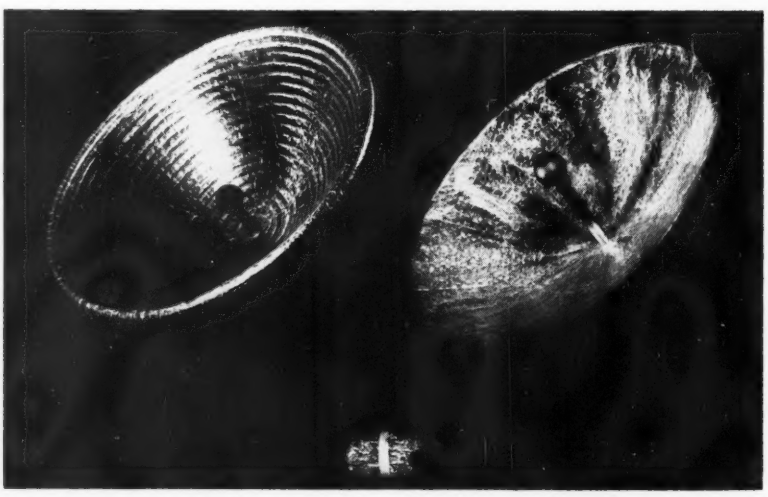
The torus is shown in the process of inflation on page 23, together with the fully inflated form. It is compartmented into four sausage-shaped links, or cells, for greater safety against micrometeorite punctures or noxious gas, which might be generated in one of the cells. The walls of the station are constructed like an automobile tire, of fabric plies and a flexible binder. Floors and furniture can also be constructed of a laminated fabric that stretches into shape as the station inflates.

15,000-lb Station

A 40-ft-diam torus was selected on the basis of the requirements previously mentioned. Such a laboratory might have a gross weight of about 15,000 lb as shown in the typical weight breakdown in the table on page 60. The table also notes that a 40-ft-diam torus including foldable floors and furniture has a weight of 2700 lb. The wall thickness is assumed to be $^3/_{16}$ in. With 7-psi internal pressure, the station walls might have a safety factor of 5 in skin stress. This assumes the use of available composite materials such as three-ply rubberized nylon or dacron with tensile strength of about 12,000 psi.

The station is heated by direct solar radiation instead of relying on surplus heat from the powerplant, which might fail. In this system the sun's rays fall on the absorbing coating, shown as a black stripe on the front of the torus, through windows in the solar collectors, shown on page 23. The remainder of the torus is coated with a reflective or low-emissivity material to cut radiation losses to space, since it is always in the shadow of the collector. Actually, if the black area is about 5 per cent of the reflective area, there should be a mean wall temperature of 70 F with a cyclic fluc-

Inflatable Solar Collectors



The collector at left is shown as packaged at bottom center of the photo.

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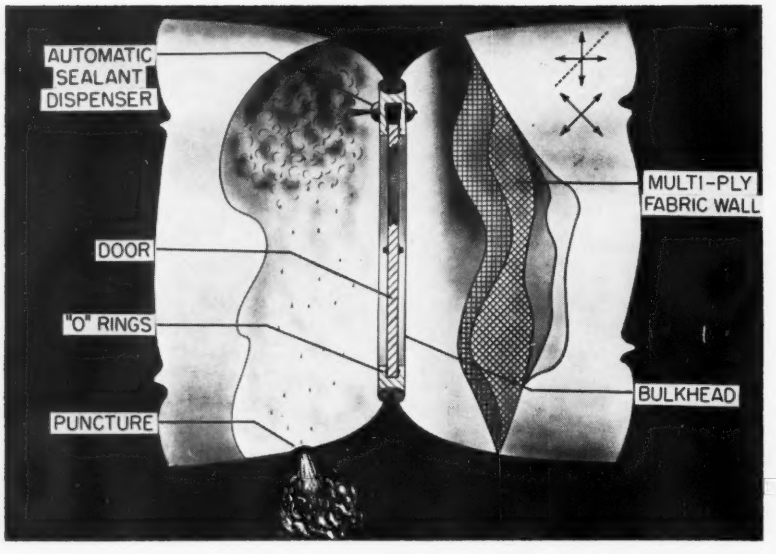

tuation of roughly 10 F, due to going from the sun to the shadow part of the orbit. The variation in air temperature would be less, probably of the order of 2 or 3 F.

The solar collector is shown fully erected on page 23. This collector is composed of a number of metal ribs so contoured that the stress balance existing between the ribs and the aluminized mylar skin curves the structure into a paraboloid. This paraboloid focuses solar radiation onto the small spherical boiler at the center. The boiler would probably be designed to evaporate mercury and thus drive a turbogenerator located at the center of the hub. The cone behind the boiler represents the heat-storage unit required to keep the powerplant operating when the station is in the earth's shadow. This entire solar powerplant might be replaced by a nuclear powerplant somewhat like the Snap II design.

A small amount of gravity, say of the order of 0.25 g, has been suggested as being necessary for human comfort over long periods. For a 40-ft-diam station, this requires a spin of about 6 rpm, which would also greatly simplify the stabilization problem. The station is sun-oriented, that is, it spins about an axis directed through the sun. To give the occupants a steady view of the earth, gimballed instrument packages which are earth-oriented might be provided. One such package is shown on the model pictured on page 23, mounted on the tripod over the boiler. This package would probably contain an infrared horizon-lock system, communication antenna, and TV camera. For a continuous view of the earth, similar instrumentation would also be required at the opposite end of the station.

As to operations, the station would be launched unmanned for safety and would automatically erect itself and go into operation upon arrival in orbit. A 40-ft-diam station weighing 15,000 lb could probably be placed into a 400-mile orbit by a Saturn vehicle. To achieve an early launch date, a minimum station 30 ft in diam and weighing about 8000 lb might be placed in a lower orbit by an Atlas-Centaur. Such a station could include a 3-kw solar powerplant like the one to be developed under Project Sunflower.

Taxi Service to Station

With the station erected and operating in orbit, an onboard telemeter could monitor the station performance. A taxi containing personnel could then be sent up to rendezvous with the station. This taxi would lock onto the airlock at the rear center of the station to transfer personnel and cargo. A typical taxi of the Dynasoar type is shown locked onto the station airlock in the model pictured on page 22. This taxi is designed to carry a two-man crew and to have enough maneuverability to make a 180-deg turn and land at a selected ground area. It is also possible, of course, that a capsule type of taxi might be utilized to rendezvous with the station.

Now that the erectable torus configuration has been reviewed, let us consider, beginning with the power supply, some of the research problems which are under investigation at NASA in connection with development of such a station.

The principal part of the powerplant under investigation to date is the solar-energy collector. Solar-efficiency tests on the mechanically erectable collector shown on page 23 have been yielding an efficiency of about 50 per cent. While this collector has the advantage of rigidity following erection, investigations are also underway on inflatable types which have the advantage of compact package size. Photographs of several of the inflatable types of collectors which have been considered are shown on page 56. The one on the left relies on concentric tubes of mylar for strength; it is also shown packaged at the bottom of the photo. The collector on the right was constructed of inflatable honeycomb made of aluminum and mylar film. This design remains fairly rigid after inflation gas leaks away. For very large sizes it is believed these collectors should be made rigid, possibly by means of an automatically hardening chemical foam introduced into the cells or tubes following erection in space, or by means of an automatically hardening skin that was originally flexible. At present, NASA is studying means of rigidizing such erectable structures.

With regard to the boiler and condenser, studies are being made of the heat transfer of fluids and gases in tubing in a space environment where gravity does not aid in the boiling or condensing processes. Since the heat-storage unit might rely on the heat of fusion of lithium hydride, which has a large thermal-shrinkage problem, studies are underway of the heat transfer between the container and lithium hydride as it cools and shrinks away from the walls. It is possible that the turbogenerator problem might be solved by utilizing hardware from the Snap II project.

Turning next to problems associated with the living quarters of the toroidal station, the question of strength of the inflatable wall might be considered first. On this page is shown a section of the toroid including a bulkhead between two cells. The cutaway section shows the laminated plies of which the wall is built. Considering any one ply, it can be demonstrated with an ordinary handkerchief that it is strong when pulled parallel to the threads but gives when pulled on the bias. Methods of alternately laying the plies at angles to each other, as shown by the sets of arrows in the figure, are being investigated to get optimum wall strength, especially in regions of compound curvature. Another promising method under investigation is a continuous winding of threads of plastic or steel, as a baseball or certain rocket motor casings are wound. Wrap angle,

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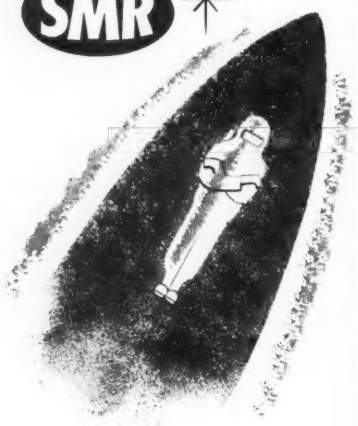

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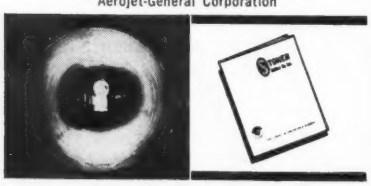
*SMR is a special Silicone Modified Rubber produced by Stoner Rubber Company, Inc.

Photo of Rocket Chamber courtesy of Aerojet-General Corporation



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Weights (lb) for a 40-ft Toroidal Space Lab

Living Quarters:	
Flexible material (including floors and furniture)	2700
Bulkheads and doors	550
Airlock	200
Air, tanks, and plumbing	950
Life-support cylinder	400
Total	4800
Auxiliary Power Unit:	
Solar collector	300
Heat receiver	100
Radiator	300
Heat storage unit	200
Turbogenerator	120
Powerplant controls	30
Miscellaneous framework, tubing	250
Shroud (nose cone)	400
Total	1700
Human Factors:	
Air conditioning	1500
Water and purification system	950
Dry food	190
Crew	350
Human factors measurement	160
Clothes, spacesuits, lights, medical supplies	300
Exercise and recreation	50
Total	3500
Shielding:	
Micrometeorite and radiation	2000
Communications:	
2-way TV	300
2-way voice radio	125
Telemeters	100
Beacon	25
Spare parts	150
Total	700
Stabilization Equipment	300
Maintenance	500
Scientific Equipment	1500
Grand Total (orbital weight)	15,000

filament distribution, and folding endurance-limits are being investigated to obtain optimum fabric design.

Assuming sufficiently strong plies, the next problem relates to the flexible binder. Experiments have been conducted at the Langley Research Center with inflated multi-ply cells like the ones proposed for the station. These have been found to be practically leakproof. Actually, however, materials must be found which, besides being impermeable, do not generate noxious or toxic fumes in a closed system and will withstand folding and packaging without damage. These materials must also be capable of surviving in space by having low vapor pressure and high ultraviolet resistance, and by not becoming brittle at low temperature or weak at high temperature in spots where the thermal-control coating may become damaged.

Even with a leakproof cell-wall construction, leakage is expected through micrometeorite punctures. Preliminary estimates show anticipated penetration of a 40-ft torus as often as once a month, resulting in punctures of the order of $^1/_{10}$-in. diam with an aggregate hole area of about $^1/_2$ sq in. per year. Since these small holes would be hard to find, automatic leak-sealing systems are being looked into. One such system consists of a container which sprays a liquid into the cell when a pressure drop occurs. The natural air currents would carry the droplets to the puncture. The sealing agent might be a vacuum-hardening liquid, such as an evaporative hardening plastic or an oxygen-stabilized liquid, or one that reacts chemically to swell the outer plies of the torus and

seal the hole. After the pressure stabilized, a dehumidifier could condense the vapor out of the station atmosphere for reuse. Other systems which may be looked into are self-sealing walls, like those on bulletproof aircraft gas tanks.

Another problem which has been considered is that of the design of vacuum-tight doors between cells and for airlocks. Doors must be large, possibly 2 or 3 ft in diam, to allow crew members in spacesuits and also cargo to pass through easily. They must be light for easy handling, capable of automatically sealing against a vacuum on either side, and not so bulky as to interfere with prelaunch packaging. One possible door configuration is shown in the drawing on page 58 sealing off the bulkhead between two cells. For lightness, the door shown would be constructed of a honeycomb core between two flat sheets. The door is elliptic in plan form as is the slightly smaller doorway. It is inserted into the double-walled bulkhead from either side, with its major axis at 90 deg to the major axis of the doorway, and is rotated $^1/_4$ turn to close it. This brings its periphery in contact with a set of O-rings. A slight pressure differential causes the door to move automatically toward the low-pressure region, sealing the door against the O-ring. Since this type of air seal is used on high-vacuum systems, such a door should hold against the hard vacuum of space.

The design work and research we have discussed here should be applicable not only to a near-earth space station, but also to long-range spacecraft and planetary bases, since the same problems of providing a long-term artificial environment for man exist for all three missions. ♦♦

New Standard of Length

The world adopted a new international standard of length at 6:00 p.m., Paris time, on October 4: The new definition of the meter is 1,650,763.73 wavelengths of the orange-red line of Krypton 86, replacing the platinum-iridium bar kept at Paris since 1889 under the Treaty of the Meter.

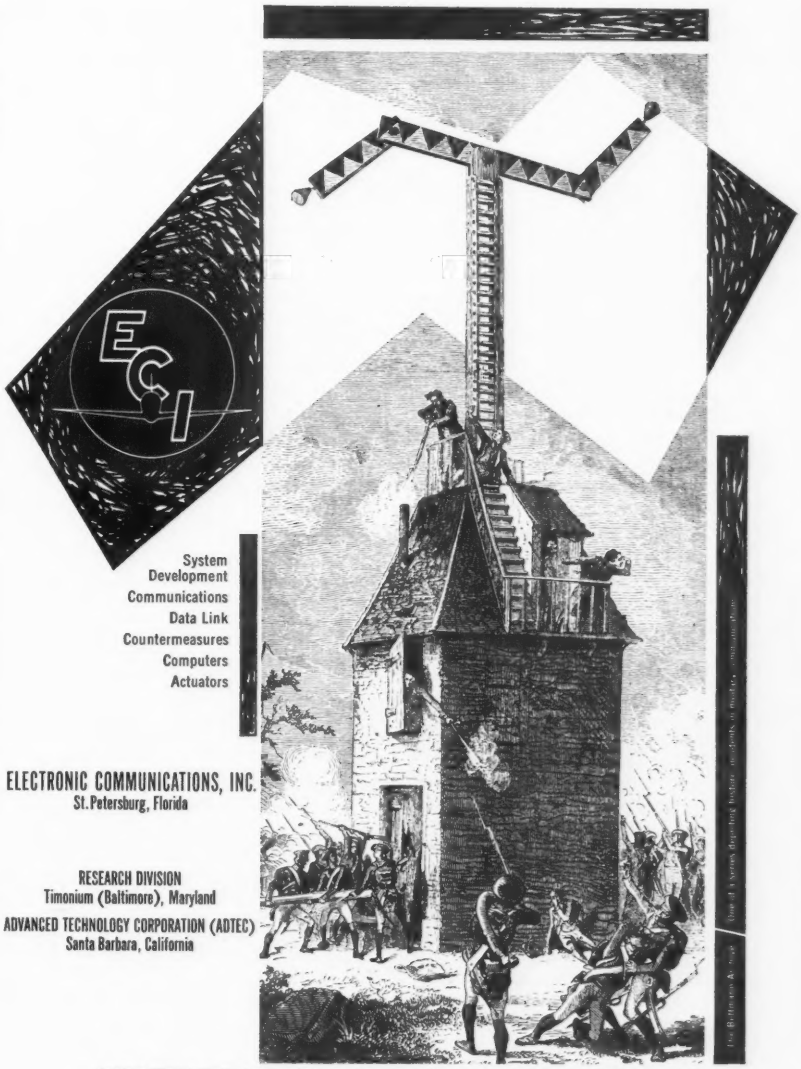
New Advisory Committees

The Dept. of Commerce has established two new technical advisory committees in response to pressures in the space program, one on calibration and measurement and the other on engineering and related services, both chaired by William Wildhack, special assistant to NBS Director Allen V. Astin.

LONG RANGE INPUT / 1794

News of the recapture of Condé from the Austrians was sped to the French Revolutionary Convention at Paris in a matter of minutes via Claude Chappe's amazing télégraphe aérienne, or relay aerial telegraph, Sept. 1, 1794. A new era in rapid communications had begun.

Today, instantaneous and completely reliable Electronic Communications insure the immediate and continuous interchange of intelligence throughout the Free World. ECI is proud of its initiative and responsibilities in the design, development and manufacture of high precision electronic equipment to the critical specifications required in various aerospace and surface roles vital to our National Defense and to scientific achievement. An example is ALRI—Airborne Long Range Input—a program where ECI communications and data link equipment fill an integral and essential requirement in linking USAF's advanced early warning system to SAGE—our continental defense network.



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ARS news

Featured speaker at the banquet, William H. Pickering, Director of JPL, addresses his audience of specialists. At the head table, from the left: Frank Faulkner of the Naval Postgraduate School; M. R. Currie, head of Hughes Research Laboratory; J. M. Sellen of TRW, meeting co-chairman; 1960 ARS President Howard Seifert (who has stepped from the table for a moment); Dr. Pickering; Ernst Stuhlinger of Marshall SFC, toastmaster; David B. Langmuir of TRW, co-chairman (hidden by the speaker); John M. Teem of Electro-Optical Systems; Sidney W. Kash of Lockheed; and O. Von Roos of JPL.

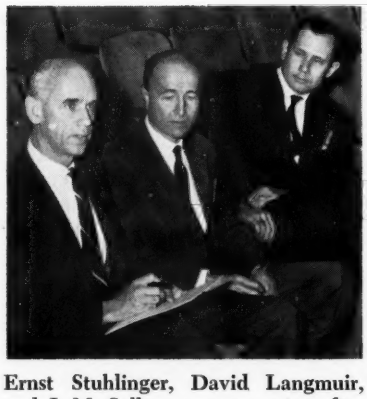
Electrostatic Propulsion Conference Called "One of the Milestones"

ATTENDED by some 200 specialists in the field, the ARS Electrostatic Propulsion Conference, held November 3–4 at the U.S. Naval Postgraduate School, Monterey, Calif., earned the plaudit, "one of the milestones in the electric propulsion project," from a foremost proponent of ion propulsion, Ernst Stuhlinger, Director of Research Projects for the George C. Marshall Space Flight Center and editor of the conference proceedings together with David B. Langmuir and J. M. Sellen Jr. of Thompson Ramo Wooldridge. A technical evaluation of the conference will be found on page 34. The proceedings of the conference will be published in the ARS Progress Series and should be available late in February or early in March.

A banquet the first day in the Ball Room of Herrmann Hall on the Postgraduate School grounds was the chief function attending the meeting. In the absence of Kurt Stehling, Dr. Stuhlinger acted as toastmaster and introduced the featured speaker of the evening, William H. Pickering, Director of the Jet Propulsion Laboratory.

Dr. Pickering commented on what must be done to make experiments in the laboratory real and successful space projects. Money, of course, he said, and going missions that will produce results and win public support for a continuing and growing space program: "The civilian space program must show returns for money invested." Like Wernher von Braun, Dr. Pickering sees a danger to the space program not in the design of experiments but in the lack of widespread commitment to excellence in the "detail of construction." We have fallen down, he believes, in the area of craftsmanship. We will be sending machines of unexampled complexity into space. These machines must work right the first time they fly. Should they add to a growing list of "spectacular failures," the space program, already the target of popular wit, could succumb to public disenchantment and official cynicism. Dr. Pickering is a man to take seriously even in his lighter moods.

This meeting was well organized and carried out. A special vote of thanks is due Prof. Frank D. Faulkner of the Naval Postgraduate School for making local arrangements. —J.N.



Ernst Stuhlinger, David Langmuir, and J. M. Sellen compare notes after the conference. Drs. Sellen and Langmuir co-chaired the conference. Together with Dr. Stuhlinger, vice-chairman of the ARS Electrostatic Propulsion Committee, they will edit the conference proceedings, which should appear by March in the ARS Progress Series.

Program Announced for Solid Propellant Rocket Conference, February 1–3

The upcoming ARS Solid Propellant Rocket Conference, to be held February 1–3 in the Hotel Utah at Salt Lake City, Utah, promises to follow up the success of the first ARS symposium on solid propellant rockets last January, which was both provocative and informative. This year's confer-

ence theme—shifting from primarily critical research topics to the engineering and technological problems—should assure a stimulating conference, as witness the program of nine Technical Sessions detailed here.

A significant feature of the program will be the Secret Sessions on the Minuteman Propulsion System on Thursday morning and afternoon, February 2, under the co-sponsorship of Thiokol Chemical Corp. and Hercules Powder Co.

Guest speaker at the banquet on Thursday evening will be the Under Secretary of the Air Force, Joseph V. Charyk. Luncheons will be held on Wednesday and Thursday, and an author's breakfast, by invitation only, each day, at which time the author's, session chairmen and vice-chairmen will meet for briefings.

For those interested, Friday will be reserved for field trips, organized by ARS Utah Section, to the facilities of Hercules, Sperry Utah Engineering Laboratories, the Marquardt Corp., Hill AFB, and Thiokol. Buses for all tours will leave from the hotel's main entrance early Friday morning.

The distaff side may take pleasure in a special ladies program arranged by the Section, which includes a luncheon, fashion show, bus tours of the Salt Lake City area, a tour of the Mormon Temple Grounds, a visit to the world famous Mormon Tabernacle Choir, attendance at a stage play at the Univ. of Utah, and a bus tour to either Alta or Brighton mountain ski resorts.

Registration fee for ARS members and those of the ASME will be $10.00. and $20.00 for nonmembers. There will be no registration fee for authors, co-authors, session chairmen and vice-chairmen, and student members. Students will not be charged, but will be admitted to sessions on a space available basis. Complete details of the technical program follow.

Wednesday, February 1

STRUCTURAL PROBLEMS

9:00 a.m. Junior Ballroom

Chairman: Max L. Williams, California Institute of Technology, Pasadena, Calif.

✦Structural Analysis of Solid Propellant Rocket Casings, B. C. F. Wei, Curtiss-Wright Corp., Wright Aeronautical Div., Woodridge, N. J. (1590-61)

✦Elastic Buckling of Cylindrical Thin Shells Under Axial and Thermal Loads, A. R. Zak and R. J. H. Bollard, Purdue Univ., Lafayette, Ind. (1591-61)

✦Stresses and Strains in Solid Propellants During Storage, G. Lianis, Purdue Univ., Lafayette, Ind. (1592-61)

✦Conditioning Capabilties of a Solid Propellant Grain, W. Weleff, Grand Central Rocket Co., Redlands, Calif. (1593-61)

✦Binder Crystallization in Polysulfide Propellant, W. E. Hunter, E. T. Foster, and G. F. Mangum, Thiokil Chemical Corp., Huntsville, Ala. (1594-61)

On the calendar

1961

Jan. 8–12	Symposium on Thermoelectric Energy Conversion, Statler-Hilton Hotel, Dallas, Tex.
Jan. 9–11	National Symposium on Reliability and Quality Control, co-sponsored by IRE, AIEE, ASQC, EIA, Bellevue-Stratford Hotel, Philadelphia, Pa.
Jan. 16–18	AAS Annual Meeting & Exhibit, Sheraton-Dallas Hotel, Dallas, Tex.
Jan. 17–19	ISA Winter Instrument-Automation Conference & Exhibit, St. Louis, Mo.
Feb. 1–3	**ARS Solid Propellant Rocket Conference, Hotel Utah, Salt Lake City, Utah.**
Feb. 16–17	Symposium on Recent Developments in Materials for Nuclear Applications, Univ. of New Mexico, Albuquerque.
March 9–10	Symposium on Engineering Aspects of Magnetohydrodynamics, sponsored by AIEE, IAS, and IRE, Univ. of Pennsylvania, Philadelphia, Pa.
March 13–16	**ARS Missile and Space Vehicle Testing Conference, Biltmore Hotel, Los Angeles.**
March 20–23	IRE International Convention, Waldorf-Astoria Hotel and N.Y. Coliseum, New York, N.Y.
March 27–31	Symposium on Temperature—Its Measurement and Control in Science and Industry, Columbus, Ohio.
April 4–6	Symposium on Electromagnetics and Fluid Dynamics of Gaseous Plasma, co-sponsored by Polytechnic Institute of Brooklyn, IRE, IAS, and U.S. Defense Research Agencies, Engineering Societies Building, New York, N.Y.
April 5–7	**ARS Conference on Lifting Re-entry Vehicles: Structures, Materials, and Design, El Mirador Hotel, Palm Springs, Calif.**
April 12–13	Symposium on Information and Decision Processes, Purdue Univ., Lafayette, Ind.
April 18–20	Symposium on Chemical Reaction in Lower and Upper Atmospheres, sponsored by Stanford Research Institute, Mark Hopkins Hotel, San Francisco.
April 26–28	**ARS Propellants, Combustion, and Liquid Rockets Conference, Palm Beach Biltmore, Palm Beach, Fla.**
May 8–10	IRE National Aerospace Electronics Conference, Biltmore & Miami Hotels, Dayton, Ohio.
May 9–11	Western Joint Computer Conference, Ambassador Hotel, Los Angeles, Calif.
May 22–24	**ARS National Telemetering Conference, Sheraton Towers Hotel, Chicago, Ill.**
May 22–24	National Symposium on Global Communications, co-sponsored by AIEE and IRE, Hotel Sherman, Chicago, Ill.
June 13–16	**Joint ARS-IAS Meeting, Ambassador Hotel, Los Angeles.**
June 19–21	Heat Transfer and Fluid Mechanics Institute Conference, Univ. of Southern California, Los Angeles.
Aug. 16–18	**ARS International Hypersonics Conference, MIT, Cambridge, Mass.**
Aug. 23–25	**ARS Biennial Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.**
Aug. 28–Sept. 1	International Heat Transfer Conference, Univ. of Colorado, Boulder, Colo.
Oct. 2–7	**XIIth International Astronautical Congress, Washington, D.C.**
Oct. 9–13	**ARS SPACE FLIGHT REPORT TO THE NATION, New York Coliseum, New York, N.Y.**

PROPELLANT PROPERTIES

9:00 a.m. **Lafayette Room**

Chairman: G. R. Makepeace, Grand Central Rocket Co., Redlands, Calif.

✦The Use of Light Metal Alloys as Additives for Solid Propellants, A. W. Blackman and D. K. Kuehl, United Aircraft Corp., East Hartford, Conn. (1595-61)

✦Plateau Ballistics in Nitrocellulose Propellants, R. F. Preckel, Hercules Powder Co., Allegany Ballistics Laboratory, Cumberland, Md. (1596-61)

✦Modification of the Burning Rates of Solid Propellants by Oxidizer Particle Size Control, E. K. Bastress, K. P. Hall, and Martin Summerfield, Princeton University, Princeton, N. J. (1597-61)

✦Oxidizer Particle Size Effects on Propellant Ballistic Properties, C. S. Brenner, Thiokol Chemical Corp., Elkton, Md. (1598-61)

✦Rheology Studies on Propellant Employing an Extrusion Rheometer, R. J. Porter, R. R. Henderson, and J. L. Hepworth, Thiokol Chemical Corp., Brigham City, Utah. (1599-61)

MANUFACTURING METHODS

2:00 p.m. **Junior Ballroom**

Chairman: (To Be Announced)

✦The Manufacture of Large Diameter Solid Fuel Rocket Motor Case Assemblies, N. J. Feola, Curtiss-Wright Corp., Wright Aeronautical Div., Woodridge, N. J. (1600-61)

✦Metallurgical Aspects of Shear Spinning, P. P. Crimmins, Aerojet-General Corp., Sacramento, Calif. (1601-61)

✦Design and Fabrication of Titanium Rocket Chambers, H. L. Podell and R. J. Kotfila, Aerojet-General Corp., Sacramento, Calif. (1602-61)

✦Recent Developments in Movable Nozzles, E. J. Hayes and S. F. Watanabe, Kelsey-Hayes Co., Detroit, Mich. (1603-61)

✦Segmented vs. On-Site Loaded Solid Propellant Rocket Engines, C. R. Voris, Thiokol Chemical Corp., Brigham City, Utah. (1604-61)

Conference Chairmen

Chairman and Deputy Chairman, respectively, of the Solid Propellant Rocket Conference, Joseph H. McKenna (right), Senior Propulsion Engineer, and John P. McGovern, Marketing Planning Engineer, Thiokol Chemical Corp., Brigham City, Utah, compare notes before the meeting.

NOZZLES AND GAS DYNAMICS

2:00 p.m. **Lafayette Room**

Chairman: James R. Kliegel, Space Technology Laboratories, Inc., Los Angeles, Calif.

✦One-Dimensional Analysis of Non-Isentropic Two-Phase Flow, E. F. Lype-Thompson Ramo Wooldridge, Inc., Cleveland, Ohio. (1605-61)

✦Experimental Determination of Nozzle Heat Transfer Coefficients with Aluminized Propellants, S. E. Colucci, C. M. Gracey, and R. S. Fairall, Aerojet-General Corp., Sacramento, Calif. (1606-61)

✦Particle Velocity Lag in Metalized Propellants, B. Brown, Hercules Powder Co., Magna, Utah. (1607-61)

✦An Experimental Evaluation of Plug Cluster Nozzles, A. Chamay, J. J. Horgan, and D. Migdal, Pratt & Whitney Aircraft, Division of United Aircraft, East Hartford, Conn. (1608-61)

✦An Approximate Analysis of Thrust Vector Control by Fluid Injection, J. Wu, R. L. Chapkis, and A. Mager, National Engineering Science Co., Pasadena, Calif. (1609-61)

MATERIALS

7:30 p.m. **Junior Ballroom**

Chairman (To Be Announced)

✦Iron-Nickel Alloys for Rocket Motor Cases, A. L. Kitchen, Curtiss-Wright Corp., Wright Aeronautical Div., Woodridge, N. J. (1610-61)

✦Recent Developments in Rocket Engine Insulation Materials, J. P. Sterry, H. I. Thompson Fiber Glass Co., Los Angeles, Calif. (1611-61)

✦Structural Plastic Materials and Fabrication Techniques, M. A. Page and E. L. McKague Jr., Thiokol Chemical Corp., Huntsville, Ala. (1612-61)

✦Non-Metallic Composite Materials and Fabrication Techniques Applicable in Present and Future Solid-Rocket Bodies, D. V. Rosato, Telecomputing Corp., Newton, Mass. (1613-61)

✦Trends in Development of Refractory Materials for Solid-Propellant Rocket Nozzles, P. A. Huppert, Aerojet-General Corp., Sacramento, Calif. (1614-61)

ROCKET AND GRAIN DESIGN PROBLEMS

7:30 p.m. **Lafayette Room**

Chairman: Geoffrey Robillard, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif.

✦A Practical Method for Compensation of Erosive Pressure Peaks, W. C. Stone, Rohm and Haas Co., Huntsville, Ala. (1615-61)

✦The Mathematical Design of a Silverless

1961 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
1961			
Feb. 1–3	Solid Propellant Rocket Conference	Salt Lake City, Utah	Past
March 13–16	Missile and Space Vehicle Testing Conference	Los Angeles, Calif.	Past
April 4–6	Lifting Re-entry Vehicles: Structures, Materials, and Design Conference	Palm Springs, Calif.	Past
April 26–28	Propellants, Combustion, and Liquid Rockets Conference	Palm Beach, Fla.	Past
May 3–5	Nuclear Applications in Space Conference	Gatlinburg, Tenn.	
May 22–24	National Telemetering Conference	Chicago, Ill.	Past
June 13–16	Joint ARS-IAS Meeting	Los Angeles, Calif.	Feb. 1
Aug. 7–9	Guidance and Navigation Conference	Palo Alto, Calif.	
Aug. 16–18	International Hypersonics Conference	Cambridge, Mass.	Jan. 15
Aug. 23–25	Biennial Gas Dynamics Symposium	Evanston, Ill.	Jan. 15
Oct. 2–7	XIIth International Astronautical Congress	Washington, D.C.	
Oct. 9–13	ARS SPACE FLIGHT REPORT TO THE NATION	New York, N.Y.	May 2

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

Rocket Engine, K. Rogers, Thiokol Chemical Corp., Brigham City, Utah. (1616-61)

✦Rapid Evaluation and Design of Spherical Motors, H. M. Segal, Aerojet-General Corp., Sacramento, Calif. (1617-61)

✦Staging Solid Propellant Rockets for Institute of Technology, Pasadena, Calif. (1618-61)

✦A Consumable Case Rocket Motor, A. N. Baxter, Space Technology Laboratories, Inc., Los Angeles, Calif. (1619-61)

THURSDAY, FEBRUARY 2

MINUTEMAN PROPULSION SYSTEM

(Secret)

9:00 a.m. — **Auditorium, Motor Lodge**

Chairman: Robert C. Anderson, Space Technology Laboratories, Los Angeles, Calif.

✦Stage Three, J. H. Main, Hercules Powder Co., Magna, Utah.

✦Stage Two, R. F. Cottrell, Aerojet-General Corp., Sacramento, Calif.

✦Stage One, P. R. Dykstra, Thiokol Chemical Corp.

MINUTEMAN PROPULSION SYSTEM

(Secret)

2:00 p.m. — **Auditorium, Motor Lodge**

Chairman: Robert C. Anderson, Space Technology Laboratories, Los Angeles, Calif.

✦Assembly and Testing, P. A. Wilson, Boeing Airplane Co., Seattle, Wash.

Motor Design and Operation

3:00 p.m. — **Junior Ballroom**

Chairman: (To Be Announced)

✦The Measurement of Heat Flux from Initiators for Solid Propellants, J. A. Keller and N. W. Ryan, Univ. of Utah, Salt Lake City, Utah. (1620-61)

✦Energies of Propellant Initiation, T. A. Erikson, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill. (1621-61)

✦On the Detonability of Solid Composite Propellants, W. H. Anderson and R. F. Chaiken, Aerojet-General Corp., Azusa, Calif. (1622-61)

✦Solid Propellant Residual Thrust Studies, J. A. Morris, Rocket Test Facility, ARO, Inc., Arnold Engineering Development Center, Tullahoma, Tenn. (1623-61)

✦Configuration Efficiency—A New Measure of Ballistic Quality for a Grain Design, J. S. Billheimer, R. A. Rossini, and T. R. Threewit, Aerojet-General Corp., Sacramento, Calif. (1624-61)

SECTION NEWS

Alabama: The Section held its Ninth Annual Honors Dinner in Huntsville on November 9.

The dinner was the climax to the Section's year of activities, which included meetings featuring speakers such as **James A. Van Allen** of Iowa State Univ. and **S. Fred Singer** of the Univ. of Maryland; participation in vocational guidance programs and work in North Alabama science fairs; providing technical consultants for several community projects; and sponsoring a series of 15 technical film lectures, open to the community, through the administrative assistance of the Huntsville University Center.

The dinner saw the presentation of three awards—two Hermann Oberth Awards for contributions to astronautics and the Martin Schilling Award. The Oberth award, to be given annually by the Alabama Section, consists of a plaque and a bronze bust of the astronautics pioneer.

The Martin Schilling Award, presented by the Alabama Section for the first time, is named for the Section's founding president, Martin Schilling, a pioneer in rocket development who directed propulsion development at Peenemuende under Wernher von Braun in 1940.

Karel Bossart, the "father of the Atlas" presented the Oberth Award for 1959 to **Maj. Gen. John B. Medaris** (USA-Ret), who won the award last year but had not formally received it because the plaque and bronze bust were not ready.

The Oberth Award for 1960 was presented by Gen. Medaris to **Maj. Gen. John Barclay,** Deputy Commander of Army Ordnance Missile Command.

The Martin Schilling Award was presented by Dr. Schilling personally to **J. W. Lee** of Thiokol Chemical Corp.'s Redstone Div., who has served as Section secretary for three years, and received the award in honor of his outstanding service to the Section during 1960.

Gen. Medaris, head of the Army's missile development program from February 1956 until his retirement from active duty in January 1960, was introduced as guest speaker by **Maj. Gen. August Schomburg,** Commanding General of the Army Ordnance Missile Command.

Gen. Medaris made predictions of several trends he expects in the missile field over the next four or five years. He predicted "that shortly the Zeus program shall be emancipated from the prejudices of its enemies." He was referring to the difficulty experienced by the Army in getting money for the anti-missile missile's development.

American Rocket Society

500 Fifth Avenue, New York 36, N. Y.

Founded 1930

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Ernst Stuhlinger, Electric Propulsion

The Pershing missile, he predicted, "may be allowed to go 800 miles." The Army is now limited to operational control of missiles with ranges under 200 miles.

"We may find a trend to less and better projects instead of more and worse ones," he stated. He explained that he was more interested in "a few giant steps out into space instead of a flock of toddling steps."

Gen. Medaris turned to education and suggested the integration of teaching physical sciences. He said the study of physics should be taken out of the liberal arts departments of schools and taught with the other physical sciences.

Much time, effort, and intelligence is wasted now, he said, because the teaching of the various sciences is not coordinated. "An engineer should crossbreed his particular discipline with others. Training programs by industry and government are now trying to do this, but this is not the way." Because education itself cannot be expected to accomplish the reforms, he said, practicing realists such as the members of the AMERICAN ROCKET SOCIETY must bring them about.

The dinner was also the occasion for announcing the Section's new officers for the coming year. Two new officers are Henry M. Shuey, president, and Walter L. Berry, vice-president.

Antelope Valley: At the October meeting of the Section, guest **Don Dirian** of the 6511th Parachute Test Group in El Centro presented an informative talk on "Parachute Recovery Systems." Data and test results on drop weights used for testing and types of parachute combinations were presented. These tests were illustrated by films of actual parachute recovery tests conducted at El Centro, Calif. The meeting concluded with a documentary film on Project Mercury. Approximately 35 members attended the social hour and meeting.

The meeting for November provided the members the opportunity of insight into the Polaris missile program. Guest speaker was **Hugo Coty** of the Lockheed Missiles and Space Div., who talked on management of the Polaris development. An informative question and answer period followed the talk. Approximately 55 members attended.

—Leslie O. Harrington

Central Texas: The September meeting of the Section, held at the Ridgewood Country Club in Waco, with about 50 members attending, heard guest speaker **Robert S. Levine,** Chief of Physical Processes Research for Rocketdyne, discuss acoustic instability in solid rockets. He presented a background of the experimental evidence and current theoretical analysis of the problem of instability in the burning of solid propellants and current means of eliminating the problem.

About 70 members attended the October meeting to hear guest speaker **G. P. Sutton,** Manager of Development Planning for Rocketdyne, discuss "The Military Mission in Space." He drew on his long experience in the field of rocket development and as Chief Scientist of ARPA to present a picture of space applications of a military nature. His talk stimulated a lively question and answer period.

—F. R. Gessner Jr.

Columbus: The Columbus Chapter of the American Institute of Electrical Engineers joined the Columbus Section of ARS for the November meeting, which was held at the Columbus and Southern Electric Co. ARS members were invited to attend the AIEE get-together dinner before the meeting. A short movie on the T2J Escape System was shown. Then

ARS Alabama Section Presents Oberth, Schilling Awards

A plaque and bronze bust of rocket pioneer Hermann Oberth, representing the highest award given by the ARS Alabama Section, were presented to Maj. Gen. John A. Barclay, Deputy Commander of the Army Ordnance Missile Command, for his contributions to astronautics in ceremonies at the Section's 9th Annual Honors Dinner, held November 9 in Huntsville. Maj. Gen. John B. Medaris (USA-Ret.), recipient of the first Oberth Award last year, made the presentation, and was guest speaker.

Also awarded during the evening's ceremonies was the first Martin Schilling Award for services to the Alabama Section. J. W. Lee of Thiokol Chemical's Redstone Div., who has been Section secretary extraordinary for the past three years, received the award from Dr. Schilling, Vice-President of Engineering and Research for the Raytheon Company.

Left, Gen. Barclay receiving the Hermann Oberth Award for contributions to astronautics from Gen. Medaris. Seated at the head table and looking on are Gen. Schomburg, Commander of the AOMC, and behind Gen. Medaris, Konrad Dannenberg, Section president, and Mrs. Dannenberg. Right, J. W. Lee of Thiokol, facing the camera, receives the first Martin Schilling Award for outstanding contributions to the Section from Dr. Schilling himself. To the left, Gen. and Mrs. Schomburg. Gen. Schomburg introduced Gen. Medaris as the evening's featured speaker, who made predictions of future trends in missiles. **(see Sections, Alabama, page 65).**

guest speaker **S. S. Meilston** of GE-Lynn talked on the fuel cell, including principles of operation, demonstration of a working fuel cell, and future aspects of cells.

—**James A. Laughrey**

Connecticut Valley: The Section members were guests of the Hamilton Standard Div. of United Aircraft at the Bradley Field Plant in Windsor Locks for their October meeting.

After an excellent dinner served in the plant cafeteria, the members were divided into groups and taken on a conducted tour of the facilities, where they were shown all the intricacies of modern multiblade propeller manufacture and control as well as the departments producing jet-fuel control systems and aircraft refrigeration units.

Following the plant tour, **William C. Kunkler,** Research and Development Manager of the Wyman-Gordon Co., gave an illustrated lecture on the application of forgings in missiles and space vehicles. Mr. Kunkler discussed the use and forging capabilities of beryllium, titanium, mixtures such as Astroloy, Rene 41, and other nickel-base alloys, as well as many refractory metals and steels. As a fitting conclusion to his talk, he presented the Wyman-Gordon film, "Hands of Giants," which demonstrated the flexibility, complexity, and control possible with the 35,000- and 50,000-ton forging presses at the Wyman-Gordon plant at Grafton, Mass. The meeting ended with a question and answer period.

Indiana. The Section had its first regularly scheduled meeting in October. **A. R. Graham** of GE discussed the principles of operation and apparent advantages of the plug nozzle. Some of the prime points cited were: Thrust-vector control without gimbaling, reduction of the combustion-instability problem, and improved facility in scaling of rocket-motor combustion chambers. Dr. Graham presented a number of slides to illustrate the various points discussed.

The meeting was closed with the showing of the movie, "The Able-Star Restartable Rocket."

The new officers elected for the coming year are: Mike Murphy, president; Jim Rannie, vice-president; Bruce Landeck, treasurer; and Mel L'Ecuyer, secretary.

—**Mel R. L'Ecuyer**

Maryland: Richard Winer, Assistant Manager of the Allegany Ballistics Laboratory at Cumberland, received the Outstanding Engineer Award of the Maryland Section at the June meeting for his work in developing the X248 Altair rocket motor, used successfully in many space shots. Mr. Winer has been with Hercules since 1943, serving in Radford, Va., Wilmington, and Cumberland. In 1953, he received the Navy's highest award, the Distinguished Public Service Award, for his work in developing new propellants for guided missiles.

Welcome W. Bender, Director of the Research Institute for Advanced Study, Baltimore, Md., the principal speaker for the evening, discussed problems that have arisen in recent years as the expanding horizons of technology have uncovered embarrassing bare spots in our basic knowledge. He reviewed possible approaches to the expansion of basic research which must be accomplished in the next decade. Bender also discussed the program in basic research being made through RIAS.

At the October meeting, **Lt. Col. George D. Colchagoff** gave an interesting lecture on "Man in Space, Challenge and Opportunities." He also showed an excellent Air Force film that graphically demonstrated many of the needs for and the desire to explore space. The meeting was preceded

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by a chicken dinner and a very interesting tour of the flight refueling plant.

Northern California: There was an excellent turnout for the November meeting of the Section, held jointly with the San Francisco Section of IAS. Our subject, "Beryllium in the Missiles and Spacecraft Industry," was apparently of considerable interest to both groups. The presentation was made by a group of scientists, including **Edmund C. Burke, Louis A. Reidinger,** and **Max E. Tatman,** from the Lockheed Missiles and Space Div.

It was noted that beryllium was a relatively rare material on the earth's surface, and extracting the metal from ore is extremely difficult. As a result, the metal still costs several hundred dollars per pound in fabricated shapes. The common method of metal shape preparation involves powder metallurgy, wherein the powdered metal is enclosed in an iron form and worked to the desired shape under vacuum and heat. Methods of inert-gas arc welding have been developed for certain applications. In general, the metal has better strength-to-weight characteristics than any other metal, but it is quite brittle and can only be worked while heated to about 1000 F. The metal also has the unusual property of retaining most of its strength up to about 1200 F. This combination of characteristics obviously makes the material of considerable interest to the missile industry, where weight and ability to stand high temperatures are critical requirements.

—**Howard M. Kindsvater**

Orlando: The November meeting of the Section was held at the Univ. of South Florida in Tampa. This was the first meeting of the Section in this area because its territory was just revised to include the St. Petersburg-Tampa area.

Dinner was served in the cafeteria of the Univ. of South Florida. The featured speaker of the evening was **Irwin Hersey,** ARS Director of Publications, who discussed "The Education Program of the AMERICAN ROCKET SOCIETY." A spirited discussion was held after his most informative talk, centering on the controversial question of experimentation by youth groups.

St. Joseph Valley: The Section held its October meeting in cooperation with several other professional societies in the area—South Bend-Mishawaka Section of the American Society for Quality Control, St. Joseph Valley Engineers Club, American Institute of Electrical Engineers, and the St. Joseph Valley Section of the ARS. Some 80 persons attended.

Guest speaker for the evening was **Maj. Robert F. Swantz,** Chief of the Instrumentation Div. in connection with the support activities of the 6555th Test Wing at the Air Force Missile Test Center, Patrick AFB. Major Swantz discussed "Aerospace Activities at Cape Canaveral," covering organization and operation of the Cape in addition to the island complex making up the Atlantic Missile Range. The presentation was concluded with a film on firings of Atlas, Titan, Polaris, Jupiter, Snark, Bomarc, and Mace missiles from the cape.

—**B. A. Bishop**

Florida Section Launches Space Technology Lectures

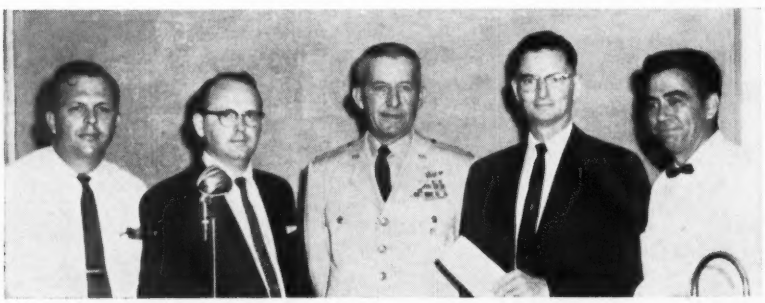
Lt. Col. Prentice Peabody, President of the Florida Section of the AMERICAN ROCKET SOCIETY, officially opened the first in a new series of Space Technology Seminars for high school teachers on Tuesday evening, October 11. The series of 14 lectures are being held at the senior high school in Cocoa, Florida, a community adjacent to Cape Canaveral.

This community service project was planned and organized by Kenneth Relf, Teacher Education Chairman for the Florida Section. Dr. Relf, a staff physicist with RCA, coordinated the project with Bradley Baker, Director of Secondary Education for the Brevard County Board of Public Instruction.

This is the second time that the Florida Section has sponsored teacher education lectures. The first series, which met with great success, was held several years ago during the time of nationwide acceleration of missile programs. Col. Peabody stated that in education fields the "cradle to grave" idea of coverage is one of the aims of the Florida Section.

The 14 lectures, held on a semi-monthly basis, will continue through May 1961 and cover such topics as Propulsion Systems, Propellants, Space Environment, Trajectory and Orbits, Guidance, Flight Path and Orientation Control, Landing and Recovery, Observation and Tracking, Scientific Space Exploration, Space Stations and Extraterrestrial Bases, Structures and Materials, and Observation Satellites.

—**Robert Eley**



Members of the Florida Section inaugurate a new series of space technology lectures for teachers at a senior high school in Cocoa. From left, Robert Eley, Section chairman for publicity; Kenneth Relf, Section chairman for teacher education; Col. G. N. Knauf, M.D., guest lecturer, who discussed the environment of manned space vehicles; Lt. Col. Prentice Peabody, Section president; and Bradley Baker, Director of Secondary Education for the Brevard County Board of Public Instruction, who coordinated the lecture series with the Section.

STUDENT CHAPTERS

Syracuse Univ.: Forty-two persons attended the first fall meeting of the Chapter in October. Guest **J. R. Cavanaugh** of GE presented a talk entitled "Milestones in the Missile Age," which was enthusiastically received by the audience. In addition to Mr. Cavanaugh's presentation, **Julius Werner,** our faculty adviser, spoke a few minutes about the space challenge and how we hope to meet it.

—**Charles E. Babcock**

CORPORATE MEMBERS

Chance Vought Corp. became the new corporate name of this third oldest aerospace company on Dec. 31. . . **Collins Radio Co.** has formed the Communication and Data Processing Div. to offer subscribers direct access to an "on-line, real-time" data processing service. . . **Douglas** has organized Astropower, Inc., an outgrowth of Aero-Space Technology, Inc., as a subsidiary to conduct advanced research into exotic propulsion systems. Douglas has sold its controlling interest in DataGraphic Systems, Inc., to General

Aniline and Film Corp. . . . **Food Machinery and Chemical Corp.** announces that production of its new Oxiron resins has been expanded to semi-commercial status.

GE's Defense Systems Dept. has named a team of 39 men to expand computer evaluation techniques and equipment for analog simulation in a move to enlarge services provided by GE Electronic System Evaluator. . . **Itek Corp.** has purchased Space Recovery Systems, Inc., Los Angeles, from **CBS Laboratories** and M. Steinthal & Co., parachute manufacturers. . . **Lockheed** intends to start the $4 million expansion of its Missiles and Space Div. this month. . . Autonetics Div. of **North American Aviation** has opened a new integrated Industrial Products facility in Long Beach, Calif. . . . **Linde Co.,** division of Union Carbide Corp., plans to build a 26-ton-per-day liquid hydrogen plant at Fontana, Calif., which will supply 21 tons per day of the fuel to NASA under a $31 million contract just awarded to Linde by NASA.

Perkin-Elmer Corp. has been listed for trading on the New York Stock Exchange under the ticker symbol PKN. . . **Philco Corp.** has announced a new $5 million building program for its Western Development Labs in Palo Alto, Calif. . . . **Republic** is undertaking a $3 million expansion of its battery of tape-controlled automatic machine tools. . . **Ryan Aeronautical** has organized San Diego main plant operations into a separate division and also established a corporate staff. In addition, the company has purchased the Electronics Div. plant and site which it has been leasing from Magnatron Corp. of America, Inc.

Space Technology Laboratories plans construction soon at Redondo Beach, Calif., of an ultramodern space research and engineering center that will house about 6500 persons. . .

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Telecomputing Corp.'s subsidiary, Narmco Industries, has purchased the research facility of Electro Instruments, Inc. . . Ground was recently broken for the new $30 million **Thiokol**-AF Plant 78 for production of the first stage Minuteman. Thiokol has formed the National Electronics Div. to take over the responsibilities of its subsidiary National Electronics Laboratories, Inc., which is being liquidated. . . The Tapco Group of **Thompson Ramo Wooldridge** has combined its electronics and power systems manufacturing operations into a single organization.

Varian Associates has created the Military Magnetics Dept. to concentrate on military applications of magnetometry. Varian and Eastern Industries, Inc., an electronics manufacturing firm, have arrived at a preliminary basis for the merger of the latter into Varian. . . Aero-Space Department is the new name of the **Westinghouse Electric** aircraft equipment department located at Lima, Ohio.

ARS Long Island Section Makes Science Awards

A much decorated man himself, Capt. Joseph Kittinger of the Air Force, right, prepares to make ARS Long Island Section astronautics awards to 23 winning students who participated in an extensive science-projects program sponsored by the Section last year. The occasion was the Section's Annual Awards Presentation Dinner. Presenting the list of award winners to Capt. Kittinger is Sigmund Kramer of American Bosch Arma, the Section's Education Committee chairman.

Sounding Rockets A Big Market?

M. Lee Rice, vice-president and head of the project engineering division of Atlantic Research Corp., presented an address titled "Business Aspects of Sounding Rockets" to the ARS National Capital Section late in September. Some excerpts from his paper:

"First, let me define the term 'sounding rocket' to mean any rocket-propelled vehicle designed to carry nonarmament packages into a desired place above the earth's surface . . .

"My current estimate of the total

budget to be expended in this field over the next five years is $50 million in 1960 and $75 million in 1961, with a fairly steady increase to $150 million by 1966. As compared with typical military programs, however, it should be noted that the expected dollar volume of the market is relatively small . . .

"There is sufficient business potential in the field of sounding rockets to warrant vigorous activity, but only as corollary activities to either an established propulsion capability or an existing vehicle engineering and fabrication capability . . .

"It is my general conclusion that under good market conditions and on the basis of recovery of development costs over a five-year period that at least one-third of the selling price must be reserved to amortize development and initial marketing costs . . .

"Since the operation is on the basis of a one-year budget, no long-term commitments are likely; for example, the purchase (from government agencies) of a lot of 500 rockets to be delivered over a 5-year period is practically unattainable . . .

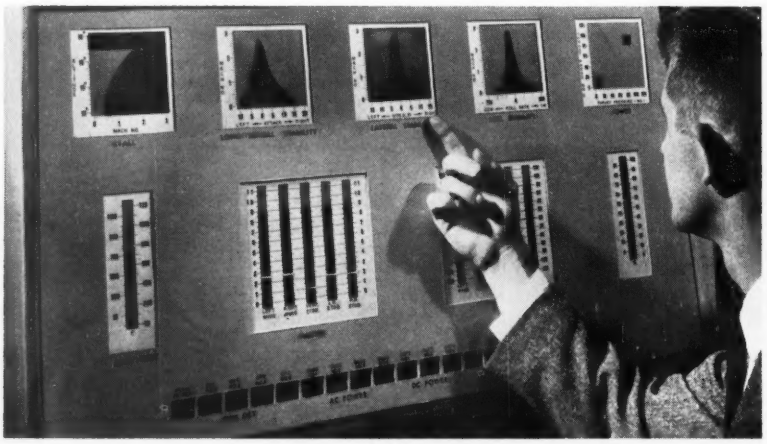
"All operations of the government are under pressure to minimize costs; thus the producer of a rocket to be offered for sale to the government will at some point, very probably with the first sale, be required to provide drawings describing the item which, in all likelihood, will be used to obtain competitive bids . . .

"The extreme competition for survival which exists in pyrotechnics exists because the industry has a capacity to produce, or develop, many times that required. Since production levels determine very strongly the profit level of the business, the entire industry suffers from an unhealthy competitive business environment (sic). The rocket industry has not reached this state as yet, and hopefully never will; however, we are much closer to this point today than many people realize . . .

"Another facet that must be considered in assessing the market for any new rocket is that many of the rockets developed for the military can be utilized in the sounding rocket field. These rockets can be offered for sale on the basis of manufacturing cost since development and qualification costs have been borne elsewhere. A second factor to be considered in this regard is that many rockets produced for weapon systems will be available to users on a very low-cost basis as the systems approach obsolescence.

"All things considered, it is my view that development of rockets for potential sale for sounding applications by using corporate capital is, at best, a very risky enterprise. Not only does one risk dollars, but since development and testing costs will often be minimized to conserve company funds, corporate reputation can suffer severely if the user experiences difficulties due to propulsion troubles, traceable to insufficient rocket development or testing prior to introduction of the rockets for sale . . .

"I do not want to leave you with the impression that I am not confident in our ability at Atlantic Research to succeed in competing for business in the sounding rocket field, and to lead the field in accomplishments. I am confident of our abilities. There are problems, however, to be faced by management in contemplating success in this field." ♦♦



Manned-Vehicle Monitor System Developed by ITT

The photo shows the panel of the Vehicle console of the monitoring system designed by ITT Laboratories for the Air Force Flight Test Center, Edwards AFB, Calif. A physiological console and panel covers pilot's heart rate, blood pressure, temperature, breathing rate and volume, and environmental data, such as radiation count. An engineer and a surgeon, interpreting the respective panel readings, advise pilot on flight procedures by voice communication.

CHANGE-OF-ADDRESS NOTICE

In the event of a change of address, it is necessary to include both your old and new addresses, as well as your membership number and coding, when notifying ARS Headquarters in order to insure prompt service. If you are moving or have moved, send the following form to Membership Dept., American Rocket Society, 500 Fifth Ave., New York 36, N.Y.

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ARDC Renames R&D Groups

The Air Research and Development Command renamed the Geophysics Research Directorate and the Electronics Research Directorate, located at Hanscom Field, Bedford, Mass., as the Air Force Cambridge Research Laboratories (ARCRL). The two directories formerly were known as the Air Force Cambridge Research Center.

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People in the news

APPOINTMENTS

NASA has promoted **Abraham Hyatt** to director of the Office of Program Planning and Evaluation. The former deputy director of Launch Vehicle Programs succeeds **Homer J. Stewart,** who resigned to return to his professorship at California Institute of Technology. **Milton Rosen,** assistant director for Vehicles steps into Hyatt's former position as deputy director.

Named to head NASA's new Test Support Office at the Pacific Missile Range is **Comdr. Simon J. Burttschell.** The office is part of the Launch Operations Directorate at Marshall Space Flight Center, Huntsville, Ala. At MSFC, **Heinrich A. Schulze** will head the new Reliability Office established there, and **Dieter Grau** continues on as director of the Quality Div., formerly the Systems Analysis and Reliability Div.

Brig. Gen. William M. Thames Jr., commanding general of the new Army Advent Management Agency, Ft. Monmouth, N.J., has named **Col. J. W. Schroder** and **Maj. L. C. Schuknecht** as systems manager and executive officer, respectively.

Lloyd V. Berkner has been elected president of the Graduate Research Center, Inc. He formerly was president of Associated Universities, Inc., where he has been succeeded by **Leland J. Haworth,** vice-president of AUI and director of Brookhaven National Laboratory, as acting president.

Thomas F. Irvine Jr., professor of mechanical engineering, North Carolina State College, has been named Dean of Engineering for the State Univ. of New York, Long Island Center, effective next month. Dr. Irvine is a member of the ARS National Committee on Liquid Fuel Rockets.

Domenic Bitondo has joined Aerospace Corp. as manager, Aeromechanics Dept., Systems Research and Planning Div.

Named to the board of directors of Astropower, Inc., a subsidiary of Douglas Aircraft, are the following Douglas executives: **Donald W. Douglas Jr.,** president; **John A. Dundas, Charles R. Able,** and **Elmer P. Wheaton;** and from Astropower, **Y. C. Lee,** president; **George Moe,** vice-president, research; and **Edward W. Smith,** vice-president, administration. **Charles Clay Noah** has been made vice-president and secretary-treasurer of Astropower. At Douglas, **J. L. Bromberg** has been appointed director of programs, defense programs.

Brig. Gen. Austin W. Betts, ARPA chief, has been slated as the new chief of AEC's Division of Military Applications.

Carlos de Moraes, former Martin Co. project manager for Dynasoar, has been named program manager for the company's Apollo study contract.

Joseph Havrylak, former manager of manufacturing, Aerojet-General's Avionics Div., has been appointed director of Midas programs within the division. **R. H. McFee,** former director of the Avionics Div., becomes director of research, Azusa plant.

Mary Beth Stearns has been appointed senior scientist in the Physics Dept. of Ford Motor's Scientific Laboratory. At the Aeronutronic Div., **Ernst H. Krause** has been named acting manager of the new Advanced Programs Staff, in addition to his present duties as director of the division's technical staff. **Robert B. Katkov** has been upped from manager, Weapons Systems Operations' Tactical Missile Systems, to general operations manager of WSO, succeeding **Roy P. Jackson,** now manager of Aeronutronic's marketing staff, and also responsible for the Aeronutronic offices in Washington, D.C.

Seymour Stein and **James E. Storer** have been promoted to senior scientists at Sylvania Electric Products Inc.

Serenus H. A. Young, former head of research and engineering program, Quenhanna Plant of Curtiss-Wright, has been named general manager, Hunter-Bristol Div. of Thiokol Chemical.

Henry Swift has been appointed assistant director of the infrared laboratory at Hughes Aircraft's Santa Barbara Research Center, and **George K. Chacko** has been appointed manager, operations research for the Semiconductor Div.

E. Gonzalez-Correa has been named manager, Microwave Dept., Philco Corp.'s Lansdale Div.

Ethridge C. Best has been appointed manager, Advanced Weapon Systems Planning; **Russel B. Hawes,** manager, operations; and **Kenneth Dollinger,** manager, advanced development, at Sanders Associates new Advanced Systems Laboratories, Burlington, Mass.

Raymond H. Heller succeeds **Robert L. Wehrli** as general manager of Robertshaw-Fulton's Aeronautical and Instrument Div. Wehrli has been appointed vice-president and assistant to the president of RF.

Bruno Uberti has joined Piasecki Aircraft Corp. as project engineer.

Peter N. Dudeney has been appointed director of engineering for Vitro Electronics, a Div. of Vitro Corp. of America.

Gordon D. Wedell, E. F. Forsythe, and **Edwin A. Boyan** have joined the technical staff of Data Systems Project Office, Ramo-Wooldridge; and **Richard H. Hill,** the Intellectronics Laboratories at RW. **John C. Howe** and **William C. Bennett** have been named district managers at the Dayton, Ohio, and Denver, Colo., field offices, respectively, for RW and STL.

William V. Wright has been appointed a vice-president of Electro-Optical Systems, Inc., and will con-

Hyatt

Stewart

Rosen

de Moraes

Katkov

Wright

Neustein

Stephens

Antonides

Steinhagen

tinue as manager of the Solid State Div. **Joseph Neustein** has been named manager of the newly formed Advanced Power Systems Div., and **Charles W. Stephens,** associate manager.

Carroll J. Peirce has joined the office of the chief engineer at Goodyear Aircraft Corp.

Paul A. Pitt, former chief engineer, has been elected vice-president, engineering, Solar Aircraft.

Charles Register, manager, ALRI Div. of Burroughs Corp., has been promoted to general manager of the company's research laboratories, Paoli, Pa., and **R. V. D. Campbell,** director of research at the labs, has been upped to corporate director of research. **Russell A. Lampman** succeeds Dr. Register, and **E. Gary Clark** will be manager of the Paoli Lab of Burroughs Laboratories.

Joseph W. Antonides has been appointed chief of engineering services, and **Carl A. Steinhagen,** chief of engineering planning, at Hamilton Standard Div. of United Aircraft.

At Minneapolis-Honeywell Regulator Co.'s Military Products Group, **Charles L. Davis** has been named vice-president and manager of all Aeronautical Div. operations; **M. P. Fedders,** vice-president and manager, Boston Div.; **W. T. Noll,** manager, Aeronautical Div. operations in Minneapolis; and **J. W. Anderson,** manager, Aeronautical Div. St. Petersburg, Fla., facility.

Melville R. Barlow has been appointed program director for the Apollo project at Convair Astronautics, and **William F. Rector III,** project leader. **A. Kahane,** director of advanced projects, will supervise Avco Corp.'s contributions in the study. Avco project manager is **Clifford F. Berninger. R. M. MacIver** has been named manager of the division's Colorado Springs office, and **R. W. Warden Jr.,** assistant to the director of military relations at Convair general offices.

Vernon Weihe will head the new Advanced Systems Planning Group set up by General Precision, Inc.

John D. Ireland has been named manager of the Advance Planning Dept., Energy Div., Olin Mathieson Chemical Corp.

Lee Crain has been made regional manager, Pacific Northwest, for McCormick Selph Associates.

Maj. Gen. Richard A. Grussendorf (AF-Ret.), former AF assistant chief of staff, has joined Hazeltine Corp.

At Bendix Corp., **J. C. Pitts** has been promoted to chief project engineer, and **Donald R. Spencer,** to engineering staff assistant, at the Mishawaka Div. **Louis C. Wells** becomes quality control manager, Avionic Products, and **Ray J. Raupp,** chief engineer, Bendix Filter Div. **David H. Brown** has been appointed general manager, Bendix-Pacific Div.

Robert W. Mason has been appointed assistant director of laboratory research at Allied Chemical's General Chemical Div.

Richard P. Carter has been named technical superintendent of Hercules Powder Co.'s Rocky Hill (N.J.) plant.

Percy Halpert, former chief, Sperry Gyroscope's aeronautical equipment engineering operations, has been appointed division manager of its Sperry Phoenix Div.

Samuel Sensiper and **William Pohlman** have been named director and associate director, respectively, of the new Command and Control Laboratories, Space Electronics Corp. **Ralph Berstein, Allan Eisenman, Arthur Garabedian, Joseph Jurca, James Richards,** and **Alex Stogryn** recently joined SEC.

Arthur Feldon, former manager of reliability, Pacific Semiconductors, Inc., has announced the formation of MicroSemiconductor Corp., Los Angeles, of which he is president.

Charles A. Hornell Jr. has been appointed supervisor of metallurgical operations, Metals Div., National Research Corp.

C. M. Wolfe has joined Borg-Warner Controls as head of transducer engineering.

Quentin G. Turner has been named program manager of development and production of the mission and traffic control B-70 major weapons system at Motorola's Military Electronics Div.

DEATHS

Victor Emanuel, 62, board chairman of Avco Mfg. Corp., died on November 26. Mr. Emanuel directed and developed such subsidiaries as Crosley Corp. and Bendix Home Appliances, Inc., and also played a prominent role in the development of public utility systems. In August 1937, he gained control of Cord Corporation, which then included Avco as a subsidiary and from there built the business empire he controlled at the time of his death. He was reported to be worth about $40,000,000 at the age of 30.

Mr. Emanuel was a philanthropic figure. For example, in 1947, he donated the Victor Emanuel lecture fund to Cornell Univ. He was a director of the Cornell Aeronautical Laboratory. In 1926, he purchased and presented to Cornell its collection of William Wordsworth memorabilia, and in 1927, gave $300,000 to the Univ. of Dayton, of which he was a lay trustee, for the establishment of the Albert Emanuel library, a memorial to his father. ♦♦

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Easily assembled and installed by non-technical personnel.

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WRITE FOR INFORMATION

Letter from Paris

(CONTINUED FROM PAGE 39)

Von Karman is, of course, also Director of the NATO Advisory Group for Aeronautical Research and Development, which recently held its 10th general assembly in Istanbul, Turkey. At the meeting, von Karman took the occasion to tour the USS Intrepid, enjoying himself hugely in the course of the visit.

Your correspondent had the great pleasure of participating in an AGARD seminar held last September in the enchanting setting of Varenna on Lake Como, and conducted by Prof. Corrado Casci of the Technical Univ. of Milan. Mainspring of the meeting, devoted to fundamental problems of astronautical propulsion, was von Karman's Gallic Director of Personnel Exchange, Rolland A. Willaume. The seminar was made up of a number of excellent lectures, delivered by such luminaries as Hugh Dryden of NASA, Luigi Crocco and Martin Summerfield of Princeton Univ., S. S. Penner of CalTech, Antonio Ferri of Brooklyn Poly, Luigi Broglio of Rome, and Eugen Sanger of Stuttgart, Germany, to mention only a few. The audience consisted of engineers and scientists of the European NATO nations.

* * *

Another result of von Karman's activities is the recently organized Aero Space International firm, founded here to foster the exchange of information between the American and European scientific and industrial communities. In announcing formation of the organization, von Karman noted:

"The tremendous progress made in the fields of the fundamental and applied sciences and the use of their results in technology point out more clearly every day the necessity of emphasizing the need, on an international plane, for exchange of information and for personal contacts between specialists.

"Unfortunately, due to a lack of continuing contact between personnel in research centers and industrial concerns in America and Europe, there is very often a great waste of effort because of needless duplication and, in some cases, hold-up in progress because of ignorance of existing ideas or techniques.

"Is it necessary for this situation to persist in an era when, in all fields and all countries, there is pressure for improving productivity and efficiency?

"I firmly believe that any efforts taken to remedy and ameliorate this situation will bring a profitable return to the men or organizations who take advantage of them."

Von Karman tries on a fighter-pilot's helmet in the course of a visit to the USS Intrepid during the 10th AGARD general assembly in Istanbul

Among the services offered by ASI are the establishment of contacts, in the form of introductions, meetings, or conferences between members of state or private institutions and companies or individuals, and the pursuance of studies on specific subjects of interest to the client requiring expert consultation by some of the best scientists in Europe.

This organization has offices at 2 Rue Joseph Sansboeuf, Paris 8, (Phone Laborde 61.25), where one can meet the amicable vice-president, Jean J. Hugot.

* * *

One of the most impressive organizations to me here today is the Societe Francaise d'Astronautique. Under the leadership of its energetic President, Prof. Edmond Brun of the Sorbonne, all the resources of the Society have been summoned for the great cause of education. But, unlike the worthy efforts of the ARS Education Committee, the French Astronautical Society centers its attention upon its adult members. In June, the Society ran a two-week course on astronautics along the lines of the course organized a few years ago by Howard Seifert under the auspices of the Univ. of California. It is of interest to note that Prof. Brun considered it more appropriate to render such service here under the auspices of the Society.

In November, the Society organized a full-day meeting in the lovely setting of a clubhouse near Paris with an impressive participation of over 100 and a very interesting technical program, in which I was privileged to take part. In addition, the Society now publishes an attractive journal, the *Revue Francaise d'Astronautique*, with articles covering a full scope of interest from "Problems Posed by the Use of Electronic Tubes on Guided Missiles" to "Galactic Noise and its Measurement." The covers of the new publication which started in June, resemble those of our *Astronautics*. Inquiries covering the activities of the Society should be addressed to the Secretary General, André Roussel, at 94 Boulevard Haussmann, Paris (Phone Europe 48.00). ♦♦

HTFMI Symposium Slated For June 19–21 at USC

The 1961 Heat Transfer and Fluid Mechanics Institute meeting will be held June 19-21 at the University of Southern California, Los Angeles, and will cover technical and scientific advances in fluid mechanics, heat transfer, and related fields—paper deadline is January 13, and final papers must be in by March 3. This year all papers will be printed in the form of Proceedings of the HTFMI.

Thermoelectricity Symposium To Be Held January 8–12

A Symposium on Thermoelectric Energy Conversion will be held January 8-12 at the Statler-Hilton Hotel, Dallas, Tex., under the auspices of the Defense Dept., acting as co-sponsor in order to show its endorsement of a new series of technical meetings dealing with the technical problems associated with direct energy conversion, and various technical societies. The papers to be read at this month's conference will discuss comprehensive developments, specific techniques, and new scientific information in this field.

Mere conventional knowledge about metals does not account for the successful welding, machining and spinning that this structure has undergone. The Budd Company has solved many of the critical problems of fabricating a reliable structure from columbium—as well as from other promising new metals such as zirconium, hafnium, beryllium, tantalum and molybdenum.

A pioneer for years in forming and welding, we are prepared to fabricate these materials today. Let us know if you want more information. Product Development Department, The Budd Company, Philadelphia 32, Pa.

PRODUCT Budd DEVELOPMENT

INCLUDING SPACEATOMICS

ASTRONAUTICS Data Sheet — *Materials*

Compiled by C. P. King, *Materials and Process Section, The Marquardt Corp., Van Nuys, Calif.*

LOW-ALLOY STEELS

Low cost and high strength are the principal properties of the low-alloy steels. These steels are made with ultimate tensile strength between 200,000 and 300,000 psi, and, depending upon duration of service, may be used at temperatures up to 800 F. They require protection against corrosion and oxidation.

Fabrication and Joining

Conventional techniques of fabrication and machining are used. All the welding techniques are applicable, but pre-weld and post-weld heating is desirable to prevent cracking.

Applications

The 17-22A was originally developed as a high-strength bolting material, but is now being used for other aircraft applications, such as brakes. The 4130 and 4340 are widely employed for landing-gear components and the newer 300M is now being used for the same purpose. The X-200 is intended mainly for rocket-motor cases.

Availability

The low-alloy steels are available as bars, billets, forgings, sheet, plate, tubing, and castings.

Corrosion Protection

Phosphatizing, chromium and cadmium plating, and hot-dip aluminizing are used to protect the low-alloy steels against oxidation and corrosion.

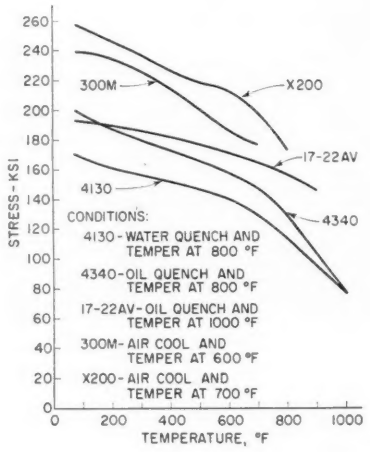
Hydrogen Embrittlement

These steels are particularly susceptible to hydrogen embrittlement when heat-treated above 200,000 psi or exposed to pickling or electroplating. Notched tensile tests will detect such embrittlement and suitable relief treatment (usually at 375 F) will remove its effects.

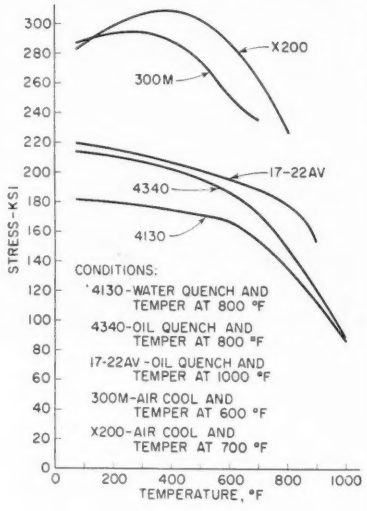
Heat Treatment of Low-Alloy Steels

Steel	Hardening Temp, F	Medium	Tempering Temp, F
4130	1525–1550	Water	400–1200
4340	1475–1575	Oil	400–1200
X-200	1700–1750	Air	600–750
300M	1575–1625	Oil	500–600
17-22A	1600–1800	Oil	800–1350

YIELD STRENGTH OF ALLOY STEELS AT ELEVATED TEMPERATURE


STRESS - KSI
TEMPERATURE, °F
300M
X200
17-22AV
4130
4340
CONDITIONS:
4130 - WATER QUENCH AND TEMPER AT 800 °F
4340 - OIL QUENCH AND TEMPER AT 800 °F
17-22AV - OIL QUENCH AND TEMPER AT 1000 °F
300M - AIR COOL AND TEMPER AT 600 °F
X200 - AIR COOL AND TEMPER AT 700 °F

ULTIMATE TENSILE STRENGTH OF ALLOY STEELS AT ELEVATED TEMPERATURES


STRESS - KSI
TEMPERATURE, °F
X200
300M
17-22AV
4340
4130
CONDITIONS:
4130 - WATER QUENCH AND TEMPER AT 800 °F
4340 - OIL QUENCH AND TEMPER AT 800 °F
17-22AV - OIL QUENCH AND TEMPER AT 1000 °F
300M - AIR COOL AND TEMPER AT 600 °F
X200 - AIR COOL AND TEMPER AT 700 °F

Chemical Analysis of Low-Alloy Steels

Steel	C	Mn	Si	P*	S*	Cr	Ni	Mo	V
4130	.28/.33	.40/.60	.20/.35	.040	.040	.80/1.10	—	.15/.25	—
4340	.38/.43	.60/.80	.20/.35	.040	.040	.70/.90	1.65/2.00	.20/.30	—
X-200	.41/.46	.75/1.0	1.40/1.75	.025	.025	1.90/2.25	—	.45/.60	.03/.08
300M	.35/.43	.65/.90	1.45/1.80	.025	.025	.65/.90	1.65/2.00	.30/.45	.05/.10
17-22A(V)	.25/.30	.60/.90	.55/.75	.040	.040	1.00/1.50	—	.40/.60	.75/.95

* Maximum content.

CUT ALONG THIS LINE

Marketing

(CONTINUED FROM PAGE 38)

weapon-system requirements, and is competitive in performance, cost, and timing with other products.

In analyzing the military market, it is most helpful first to gain an overall understanding of the trend of total military expenditures. This forces you to study economic, political, and social factors on a worldwide basis. However, the caution here is not to get carried away with compiling numbers of a general nature unless they actually will provide a tool for current forecasting or develop background data for long-range planning. Long-term trends of total military expenditures are of no value unless they are a building block which will help you to focus on a specific product area of interest to your company.

A typical analysis of military spending could take the following sequence: Total DOD Expenditures; Missile Procurement; Aircraft Procurement; Space Procurement (NASA); Research and Development; Specific Product Areas: Airframe, Electronics, Propulsion, Ground Support.

This budget analysis should focus down as low as possible in order to highlight those areas most significant to your company's particular needs. For instance, in propulsion, the short- to medium-range forecast must show the distribution of rocket expenditures between liquid and solid-propellant types; who uses them (service) and for what applications (missiles vs. space). In the long-term analysis it should show how long liquids and solids will continue to increase and when nuclear rockets and other advanced propulsion systems will begin to make a significant penetration of the propulsion market. Unless you can focus down this low and come up with a worthwhile analysis and interpretation for planning purposes, you are not giving your management the kind of information it needs.

Distribution of the market by customer and application is a vital tool in planning marketing strategy. Your particular product area should, therefore, be broken down by service and weapon-system type. By comparing this information with data from your own company, you may be able to determine where company effort should be increased or even if it should be redirected. The following is an example of typical consumer-industrial marketing questions translated into military marketing terms, a sort of Military Marketing Questionnaire:

Which services use your particular product?

How often do they use it (production requirements)?

On what types of systems do they use it?

What are the performance parameters required of your particular component as dictated by the end product in relation to weight, mobility, size, storage, temperature, strength, maintenance, serviceability, etc.?

What is the alternative to your product in terms of operational theory, application type, or product (manned vs. unmanned, air-launched vs. ground-launched, solid vs. liquid, etc.)?

How are the performance requirements developed?

How are sales made?

What is the average development period? Average length of production run? Average quantity per system type? Average cost?

How will the above criteria change in the future with respect to your product?

How important is cost vs. performance?

A meaningful customer analysis should include not only the shifts in

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Propulsion System and Power Cycle Analysts

Select Opportunities for outstanding . . .

- PHYSICAL CHEMISTS
- MECHANICAL ENGINEERS
- CHEMICAL ENGINEERS

Several select positions are now available in an analytical group engaged in performance analysis of systems that will represent significant advancements in the state of the art — advanced hypersonic air-breathing propulsion systems, nuclear power-cycle concepts for auxiliary space power-units, air-transportable power-packages and central power-station equipment. Studies require objective imagination and a wide range of scientific and technical skills.

Programs are of the long-range sustained type and have excellent management support. Readily available are superior analog and digital computer services and contributing efforts by experienced specialists with complementary skills.

These are attractive opportunities at a level that will interest outstanding technical men. Minimum qualifications include an advanced degree plus related experience.

Write in confidence to
MR. W. V. WALSH

RESEARCH LABORATORIES
UNITED AIRCRAFT CORPORATION
400 Main Street, East Hartford 8, Conn.

procurement within a particular service, but also the interaction among the various services themselves. For instance, try to show the effect upon your company of such things as the result of limited-war weapon spending by the Army; cancellation or reinstatement by the Air Force of Bomarc B, B-70, etc.; increase in Navy spending for ASW, Polaris, nuclear subs, aircraft carriers; changes among the services as they compete for space age responsibility.

Needle in the Haystack

Your company's share of the market should be the needle in the military procurement haystack you are looking for. How well your company does in the future is a function of the size of the potential market, the intensity of competition, and your ability to be superior both technically and cost-wise. Your major competition should be forecast for as long a period as you forecast your own sales. A general trend line is helpful but you should strive for as much detailed background data as possible.

If the sales forecast cannot be developed by product or program, the following tabular system can be used. Starting with the current year, list every product and related program in which the competition participates. If the dollar value is known, put it in. Then, going out every two or three years, make the same type of list while phasing in and out those programs which you think the competition will get. You may not arrive at total volume through this type of analysis, but it will enable you to get order-of-magnitude figures and possibly to discover areas of concentration, as well as strengths and weaknesses.

When you develop a good "feel" for the total market, you should do a "key product" analysis. Select the most important future programs for your particular product area, and determine how your company and its leading competitors will look with and without these programs. You may even be able to prove that if your company does not win government R&D support in a particular area, company funds should be expended to maintain a strong competitive market position.

In analyzing your competition, you should evaluate not only dollar volume and number of programs, but also the types of unique and costly facilities, as well as numbers and types of highly specialized personnel. This is important because cost does not always determine a contract award. The areas assessed by the military in most proposal evaluations are as follows: Technical Content, Availability of Facilities, Availability of Manpower, Realism of Programming, Cost Estimating, History of Past Performance, Management Capability.

In many cases, technical experience, facilities, and manpower availability carry the most weight. As a result, distinct areas of competition and even monopoly can develop among certain companies by reason of existing facilities and experience in certain critical areas. Examples in the propulsion industry are large liquid engines, liquid hydrogen, and large solids. Such situations should be examined closely, since thousands of dollars of proposal money, as well as valuable engineering man-hours, can be saved by avoiding those areas in which the company would be just "going through an exercise."

Success in any market means "knowing what the customer wants and giving it to him." Each military group should be analyzed in terms of the basic definition of just what it really is and what its areas of responsibility are. Only then can you understand what tools are needed for the job. Among the basic facts which should be known are the responsibility of the different services in nuclear war, in limited war, in anti-missile defense, in anti-submarine warfare, and in military space operations. Particular attention should be given to any limitations concerning range and payloads, as well as strategic, tactical, and air-defense operations. You must also try to estimate what changes will take place in the next three, five, and 10 years.

A "roles and missions" analysis will provide the necessary background for an analysis of current weapon-system requirements and for extrapolation of these requirements not only for follow-on type systems, but also for the development of new ideas and new concepts. A company should not be content with merely replying to requests for proposals from the military. The most successful companies are those which aggressively pursue new ideas and concepts and constantly approach the military with unsolicited proposals.

Weapon-system-requirement analysis is a study of the tools the various services need to accomplish their roles and missions. Range, altitude, speed, and timing are important characteristics to know about weapon systems. However, their improvement and progression in follow-on systems should be interpreted in terms of what they demand of your particular component: Size, weight, duration, temperatures, etc.

The following scoreboard is one of many examples to show what can be done with weapon-system analyses and forecasts. This table demonstrates

A SUDDEN RUSH OF WATER
MODEL 8300
Drench shower and emergency eye-wash combination. Pull ring opens slow-self-closing valve releasing a torrent of water. Eye-wash is operated by foot treadle; twin fountain heads direct streams of soothing water into the eyes.
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Injurious chemicals are instantly washed away by the cascading water from Haws Drench Showers. Simple pull-chain or foot treadle valves release a sudden rush of water—saving valuable seconds until medical help arrives. Chances of permanent injury are minimized, and insurance claims correspondingly lessened. HAWS Emergency Drench Showers are available in models to meet virtually any industrial need. WRITE TODAY—to find out the full story!
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a method whereby the future trend in number of missile systems in production by operational mission can be analyzed. The numbers used in this example are arbitrary figures. Such a table should show the progression of weapon-system types necessary to provide the services with a well-rounded and diversified missile arsenal, not only for an all-out nuclear conflict, but also for brushfire or limited type wars.

Missile Scoreboard

	1960	1964	1967	1970
Strategic	6	4	4	3
Air Defense	10	14	9	4
Tactical	8	12	10	8
Total Missiles	**24**	**30**	**23**	**15**

Many variations of this type of table can be made. The propulsion man can break the table down in terms of liquid- vs. solid-rocket trends; the electronics man, in terms of guidance systems. This type of table can also be made for space systems, aircraft, ships, or ground vehicles.

A study like this can also be used as backup to show when missile spending will start to decrease and the space era will really begin. It will help to pinpoint the period when your company must become more space oriented.

The actual development of a product is the responsibility of the technical staff. However, effective market research can supply many facts which can help the technicians do a better job of product development. It is as simple as this: The scientist's job is to build a better mousetrap, while the role of market research is to make sure that when he is finished there will be some mice around. The main objective is to sell a product that (1) satisfies a need, (2) is accepted by the customer, and (3) is superior, or at least as good, as that of the competitor. Market research can supply these answers even in the military market. In fact, product development should be the end result of marketing research.

It must be remembered that because a request for proposal on a certain system does not exist, it does not follow that you cannot gain military support. In these cases, you must determine how badly the military needs this new concept to fulfill its mission, how feasible the system is, and how much money can be found to support it.

Do not always expect to substantiate the need by military documentation. For long-term requirements, you must rely heavily upon your intuition, logical extrapolation, and philosophical analysis. This is the main difference between military marketing research and consumer-industrial types. Because of the cloak of security and the nebulous scientific areas involved, many management decisions must be made without conclusive, documentary data. This is where a sound, logical, and penetrating market analysis can contribute most toward easing doubts concerning future military products.

Market research can also play an important role in determining customer acceptability of a product. Evaluation must be made in terms of performance, timing, and cost.

Performance and availability of the product must be evaluated against customer requirements. Market research cannot only make the evaluation but should also list in advance the performance goal and major milestones the program must meet to insure success. Proposal deadlines, design and test dates, plus production and operational targets should all be a vital part of the data issued by market research.

In most cases a market research analyst can be more objective concerning costs than someone working on the project. Many times, scientists and engineers can be carried away by the fact that they are working on a new and unique solution to a problem. It is easy for them to forget that someone has to pay the bill and that the company is in business to make money. Market research can do much to inject realism in the pricing of the proposal by setting up cost targets.

To determine the competitive status of a proposed new product, those items which are analyzed to determine customer acceptability must now be analyzed against competitive parameters. In this case, technical competence, timing, and cost must be evaluated to determine where you stand relative to the competition.

You may find it most enlightening to conduct a "corporate image" analysis. Individual products can be evaluated in these areas, but so can the company as a whole. Through a survey of the military customer and other companies in the defense industry, you should be able to determine how your company is rated from the standpoint of technical competence, ability to meet schedules, and realistic pricing. It may not always be necessary to start an advertising campaign to change this image. It can be done quietly but effectively by applying realistic and objective criteria developed by market research to the product-planning operation.

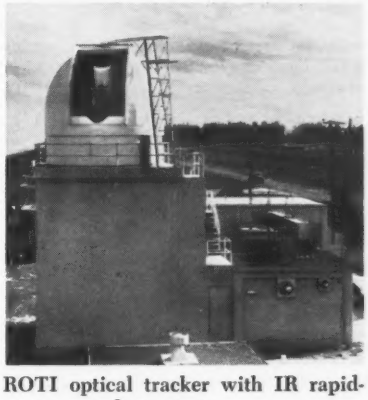
The preceding examples illustrate the fundamental characteristic of market research. It can be a most valuable aid to decision making in the military market. If used properly, it can make the sales operation more effective, and product planning and development more realistic. It is today a major factor in selling to the military.

♦♦

Developing "Missile Signature"

A 24-in.-aperture optical camera (ROTI) at Melbourne Beach, Fla., 15 miles south of the AF Missile Test Center, has for some time been tracking missiles in conjunction with an 8-in.-aperture infrared rapid-scan monochromator, which can be seen black against the optical camera barrel in the accompanying photo. Perkin-Elmer developed the two tracking instruments and is using them to make a study of missile exhausts for AFCRL under ARPA sponsorship in the Interservice Radiation Measurement Program.

Although IR measurement of missile exhaust, midcourse characteristics, and re-entry phenomena are still in the early stages of development, such research may make possible missile "signatures" for use in defense warning systems, as well as contribute to the development of IR homing systems, decoys, and means of tracking.



ROTI optical tracker with IR rapid-scan monochromator.

ASTRONAUTICS Data Sheet — *Propellants*

Compiled by Stanley Sarner, *Flight Propulsion Laboratory Dept., General Electric Co., Cincinnati 15, Ohio*

Hydrogen Peroxide (H_2O_2)

Hydrogen peroxide has been widely used both as a monopropellant, especially in auxiliary power and reaction control units, and as a bipropellant oxidizer. The 90 per cent concentration has been the common type, but the recent availability of the 98–100 per cent concentration should result in a changeover. The oxidizer is capable of being used as a regenerative coolant, and can be considered to some extent to be a "ready" propellant. Its high freezing point and the need for venting during storage due to decomposition are its major disadvantages. The accompanying tables give some of the properties of 100 per cent hydrogen peroxide.

Hazards

Seventy-five per cent or higher H_2O_2 in water may produce vapor concentrations which are explosive. The lower limit temperature for the explosive region is 110 C for 100 per cent H_2O_2 and rises to 128 C for 75 per cent H_2O_2.

Hydrogen peroxide is not toxic in the usual sense, and inhalation of vapors saturated at room temperature for moderate periods of time, such as might occur in gross spillage, is no respiratory hazard. The oxidizer is a strong primary irritant to the skin, causing whitening and itching, but flushing with water usually relieves this, and no aftereffects are noted. It is highly irritating to the eyes and may lead to injury. In case of contact, the eyes should be flushed with water and medical attention obtained immediately.

H_2O_2 in 98-100 per cent concentrations is immune to mechanical impact such as in drop weight or rifle-fire tests, and it is apparently impossible to set up a self-propagating detonation through the action of No. 6 or No. 8 blasting caps. Definite explosive effects have been noted only under the influence of powerful booster charges combined with a high degree of confinement. Concentrated solutions must be protected against contamination; otherwise, they may decompose at a dangerously high rate.

Materials for Handling

In general, materials suitable for use with 90 per cent H_2O_2 are also suitable for 98-100 per cent H_2O_2. Some plastics are more severely attacked by the more concentrated solution, but the concentrated H_2O_2 is more stable on contact with metals. Types 1060 (99.6), 5052 and 7072 aluminum are very suitable for use with 98-100 per cent H_2O_2. Types 6061 aluminum, 356 cast aluminum, 304, 316, and 347 stainless steel are less desirable. Types 2024 aluminum and 355 cast aluminum are unsuitable. Teflon is the best elastomer, with Kel-F, polyethylene, and Vinylite Vu1930 less desirable. Halocarbon oils and Fluorolubes are satisfactory lubricants.

All materials should be scrupulously clean and metals should be passivated. Care should be taken to avoid any foreign matter or easily oxidized substances.

Cost and Availability

H_2O_2 in 98-100 per cent concentrations is readily available in 300-lb net containers, tank trucks, and tank cars. Currently quoted prices in tank cars are: 90% H_2O_2, 50¢/lb; 98% H_2O_2, 60¢/lb; 99% H_2O_2, $63^1/_2$¢/lb.

Physical Properties of H_2O_2

Boiling Point	150.2 C	302.4 F
Freezing Point	−0.435 C	31.217 F
Triple Point	−0.42 C	31.24 F
Critical Temperature	457 C	855 F
Critical Pressure	214 atm	3145 psia
Density at 25 C (77 F)	1.4422 g/cm^3	90.037 lb/ft^3
Vapor Pressure		
at 25 C (77 F)	1.95 mm	0.038 psia
at 80 C (176 F)	49.1 mm	0.949 psia
from 75–450 C (167–842 F)		

$$\log P\ (mm) = 44.5760 - \frac{4025.3}{TK} - 12.996 \log TK + 4.6055 \times 10^{-3}\, T\,K$$

Viscosity		
at 0 C (32 F)	1.798 centipoise	—
at 25 C (77 F)	1.156 centipoise	—
at 50 C (122 F)	0.819 centipoise	—

Chemical Properties of H_2O_2

Heat of Formation (liquid) at 25 C	−44.780 kcal/mole
Heat of Vaporization at 25 C	12.334 kcal/mole
at Boiling Point	11.260 kcal/mole
Heat of Fusion at Freezing Point	2.987 kcal/mole
Heat of Sublimation at Freezing Point	15.510 kcal/mole
Heat Capacity, 0–27 C (32–81 F)	21.36 cal/mole−C
Explosive region	above 110 C
Maximum allowable concentration in air	1.0 ppm

Theoretical Performance of H_2O_2*

Fuel	Specific Impulse (sec)		Chamber Temperature
	Frozen Flow	Equilibrium Flow	Deg K**
100% monopropellant	163	—	1285
90% monopropellant	147	—	1023
C_2N_2	265	274	3200
N_2H_4	281	286	2923
UDMH	276	283	3008
H_2	322	323	2404
B_5H_9	309	316	3400

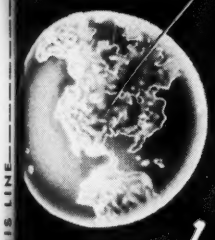
*P_c = 1000 psia; P_e = 14.7 psia; optimum O/F ratio

**Corresponds to equilibrium flow impulse.

CUT ALONG THIS LINE

BEECH "IMAGINUITY" IN *Cryogenics*

BEECH "HEAT TOWER" AT BOULDER . . . The only facility of its kind in the country where it is possible to ground-test a complete cryogenic fuel system under all temperature conditions encountered from launch to burnout, this new Beech thermal heat laboratory has been given a leading part in establishing new design criteria for lightweight tank assemblies for future missile or space vehicles.



2

AS "MISSILE" ACCELERATES, fuel is programmed out of the tank and outside pressure reduced, while temperature can be elevated to as high as 1,000° F to simulate actual conditions of fuel consumption and aerodynamic heating. Temperatures of 1,500° F or more can be produced.

1

LIQUID HYDROGEN AT –423° F, in an insulated titanium tank developed by Beech, is lowered into giant vacuum bell lined with 3,000 infra-red quartz lamps, in preparation for simulated rocket launch.

3

BY "BURNOUT" TIME, vital information that will influence future design of complex cryogenic fuel systems has been gathered for processing through electronic computers—all without ever leaving the ground!

Beech "space flights" at Boulder, Colorado . . .

Pioneering in testing of space vehicle components ...including liquid hydrogen fuel tankage systems

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Beech Aerospace Division projects include R&D on manned aircraft; missile target and reconnaissance systems; complete missile systems; electronic guidance systems; programs pertaining to liquid hydrogen propellants and cryogenic tankage systems; environmental testing of missile systems and components; and GSE. May we help you? Write, wire, or phone Contract Administrator, Beech Aircraft Corp., Wichita 1, Kansas—or nearest Area Office.

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CUT ALONG THIS LINE

Missile market

By Jerome M. Pustilnik, *Financial Editor*

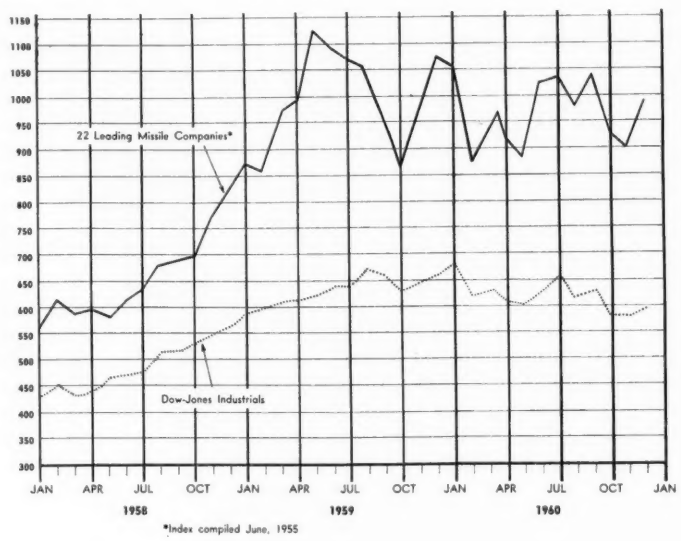
"PRECISION Engineering Applied to the End of a Wire"—this is the motto and business philosophy of AMP Inc., once a pioneer and, today, a leading factor in the fast-growing electrical terminals industry.

Through devotion to this precept, the company's sales and earnings have grown strikingly. Moreover, AMP has attracted important investor interest.

Serving a broad spectrum of electrical and electronic end-uses—from appliances to telecommunications—the ubiquitous connector is as vital to these product's as tires are to the automobile, and as easily taken for granted. In 1960 the termination industry's sales growth should result in total factory sales of about $150 million, illustrating its importance. Why, then, are investors only lukewarm toward this industry? And why is it AMP that they are now favoring?

Two unfavorable characteristics of this industry—severe price competition which has caused low profit margins and fluctuating earnings and, perhaps as a result, pronounced sales declines during periods of business recession—explain why investors have tended to bypass it. AMP has overcome these problems. Unlike its competitors, it has avoided the mass production of standard connectors and concentrated, instead, on advanced types of proprietary items developed through its extensive R&D programs, plus strong patent protection.

A broad approach to solving the increasingly important and complex problems of electrical terminations and connections has been AMP's philosophy since its founding in 1941. From the beginning, the company realized there was more than just a simple mechanical problem of somehow attaching a wire to something. All termination devices should have the proper electrical characteristics, complement and improve the design of the device in which they are used, and be applied as economically and reliably as possible. By continuously spending about 14 per cent of sales for R&D, AMP produces a steady flow of new products to fit innumerable applications and to keep pace with the fast-changing technologies of the electrical and electronic fields. The company maintains a staff of more than 500 in R&D and engineering activity, most of them graduate scientists and engineers.



	Dec. 1960	Nov. 1960	% Change	Dec. 1959	% Change
Dow-Jones Industrials	595	580	+2.6	659	−9.7
Missile Index	980	900	+8.9	1076	−8.3

The hard core on which AMP's expanding business is built is the solderless connector and technique. By varying the size, shape, metal, insulation, and plating and by introducing such other characteristics as environmental sealing, disconnectibility, self-cleaning action, etc., each termination can be designed to meet exacting requirements. This adaptability has enabled the solderless technique to achieve phenomenal success over previous methods, particularly for miniature and disconnectible applications where solder would be impractical. Furthermore, total termination costs are often drastically reduced by the speed, simplicity, and uniformity of application. AMP's solderless technique frequently allows dramatic improvement in the design of an entire device and the production methods and facilities in use.

For these reasons, AMP is the leading manufacturer of solderless terminations, supplying more than 40 per cent of the market, almost twice as much as its nearest competitor, although no single company competes with AMP on all its product lines. Among its 3500 customers are virtually every important producer of electrical equipment and electronic devices. To provide for their requirements AMP produces more than 15,000 types and sizes of terminals and connectors—ranging from a simple single wire terminal to a 200 contact cable connector, and including environmentally sealed, two-piece, pin and socket edge connectors for printed circuits, and taper pin and block techniques which aid modular assemblies. To assist customers in clamping terminations to wire and cable quickly and properly, AMP produces and sells a line of precision hand tools; and also leases, to its volume customers, automatic machines which apply terminals (fed into the machine in strip form from large reels) at high speed.

The company's sales approach

shows still another aspect of its carefully thoughtout business philosophy. Unlike its competitors, AMP does not sell from catalogs nor through manufacturer's reps, but rather through its own organization of sales engineers and salesmen. Important customers and accounts requiring more technologically advanced products and those needing a "creative engineering" study—which may extend to the design of their entire unit, not merely its termination requirements—are served by 50 sales engineers. More than 200 other salesmen, working out of a score of regional offices, sell general products and cover the repair and replacement markets.

The Capitron Div. produces mica high voltage capacitors used in radar transmitters, power supplies, and pulse forming networks. While Capitron contributes only 4 per cent of sales, it is growing steadily.

The company's Syscom Div. is its newest and fastest growing activity. Syscom's sales contributed 12 per cent of AMP's 1959 total, compared with only 3.5 per cent in 1957. Syscom produces patchboard programming systems for analog and digital computers and their peripheral equipment and for test equipment such as circuit analyzers. A new product, MAD ferrite cores (Multiple Aperture Device) looms large in Syscom's future, although current sales are negligible. MAD devices are beginning to be used in shift registers and computer memory-logic units.

Another rapidly growing activity is the international field. Starting in 1952, wholly-owned subsidiaries have been established in Europe and Asia; and their success has been phenomenal, for sales grew from $1.3 million in 1956 to an estimated $9–10 million this year. Competition abroad is still limited, management believes. The main hurdle seems to be overcoming the reluctance of many potential customers to accept AMP's advanced electrical components for their products. New subsidiaries are in the planning stage, including units for the South American market. The company believes it can maintain the splendid growth rate of its foreign business over the next several years. Another wholly-owned subsidiary, Pamcor, Inc., conducts manufacturing operations in Puerto Rico, where it benefits from the liberal tax concessions granted by the island's government.

While AMP reports to its stockholders have not consolidated domestic and foreign results, they are likely to do this soon. In the following figures, this column has consolidated them, for the past as well as for future estimates, for purposes of clarity. They show that sales have grown from $21.6 million in 1955 to $48.4 million in 1959, while earnings leaped from $0.80 to $2.50 per share. After-tax profit margins ranged from 7.4 to 10.5 per cent. This column believes sales could reach $59–60 million in 1960, with earnings of $3.00 per share in prospect. And if the economy's current softness is neither prolonged nor pronounced, 1961 could witness similarly worthwhile gains. With this record and these prospects, it's easy to like AMP.

AMP, listed on the New York Stock Exchange, has $1 million of long-term debt and 2,017,496 common shares outstanding. ♦♦

In print

Nuclear Flight, The United States Air Force Program for Atomic Jets, Missiles and Rockets, Edited by Lt. Col. Kenneth J. Gantz, USAF, Duell, Sloan and Pearce, New York, 1960, 216 pp. $4.00.

In spite of the formal disclaimer in the introduction, "Nuclear Flight" is probably the most authoritative compilation of AF opinion and conclusions on this subject available to the general public. The book is made up of 22 articles written originally for a special issue of the *Air University Quarterly Review*, the professional journal of the USAF. In view of this origin, it is not surprising that the first of the four major sections is devoted to a discussion of AF interests in the field of nuclear propulsion and power generation and background information on AF and AEC projects involved in the development work.

The second section gives a very brief review of the principles of nuclear reactors, thrust and power production from nuclear energy, heat transfer and coolant systems, reactor materials and shielding problems. The review is limited to qualitative discussions of the various subjects and serves as a short refresher course in preparation for the more detailed chapters that follow.

The next section gives the status of each of the major programs as of the summer of 1959. The projects covered are the nuclear airplane (ANP), both direct and indirect cycles; nuclear ramjets (Pluto); nuclear rockets (Rover); nuclear auxiliary power supplies (Snap), including reactor and radioisotope sources, and radiation effects on aircraft systems. All but the last of these chapters were written by senior representatives of the AF or AEC contractors responsible for the technical programs. Each chapter presents a concise summary of the objectives of the project, a discussion of the approaches being taken, a description (varying in detail) of the equipment being developed, and facilities for development and testing.

The final section is entitled "The Human Element" and discusses the special problems related to the use of nuclear aircraft. Topics include the crew environment, ground support, and public hazards.

A short glossary of terms is supplied as an appendix. It contains the somewhat incongruous combination of nuclear and space terminology interspersed with Washingtonese that appears to be needed to describe R&D work in this field.

The wary reader might be suspicious of the objectivity of the book since it has been written by AF officers and government contractor representatives. It is true that the overall pictures of goals and progress have a rather rosy tint, but the discussions are basically factual, with considerable space devoted to the problems that remain to be solved.

Scientists and engineers looking for detailed technical data will be somewhat disappointed in "Nuclear Flight." Both the lack of space for detailed discussions and rules of security classification limit the amount of detail provided. On the other hand, the book should prove valuable to the individual wanting a comprehensive survey of the subject. It presents in organized form technical and descriptive material that is otherwise available only in isolated bits. The first section of the book, dealing with the motivation and

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organization of the several projects, should be valuable to prospective AF and AEC contractors, and will be fascinating to students of government organization.

—R. E. Schreiber
Los Alamos Scientific Laboratory

Space Biology by James S. Hanrahan and David Bushnell, Basic Books, New York, 1960, 263 pp., illustrated. $6.00.

Now that the layman has a choice of a dozen or so general books on space flight, publishers are turning their attention to specialized areas of astronautics likely to attract the interest of the public. One of the earliest such entries is this volume, co-authored by two historians from the AF Missile Development Center at Holloman AFB.

The book is a straightforward, carefully documented account of the efforts now being made to send man into space and bring him back safely to earth. Beginning with a brief introduction which reviews the literature of manned space flight for the past two millenia, the authors proceed in a logical and orderly fashion to an examination of the vehicle in which man will make his journey (the question of air pressure, cabin atmosphere, and food, water and waste products), g-forces and weightlessness (centrifuge experiments, impact forces, anti-g devices, and rocket and aircraft weightlessness experiments), and, finally, the radiation hazards.

Of particular interest, although not exactly in line with the title or intent of the volume, is the last chapter—a consideration of the impact of astronautics on mankind. While this has little if anything to do with space biology, and rather reflects the interest of the authors in an entirely different but very provocative subject of great concern to most astronautical engineers and scientists, the topic has been discussed so little in books of this type that the chapter constitutes a welcome addition to the literature. Covered in the chapter are the philosophical implications of space flight, its economic impact, and its influence on religion, government, and politics, education and the arts.

Sum-up: An interesting introduction to space biology for the layman, plus an added dividend in the form of that excellent final chapter.

—I.H.

Beyond the Planet Earth by K. E. Tsiolkovskii, translated by Kenneth Syers, Pergamon Press, New York, 1960. $3.75.

This little novel, conceived in 1896 and published in 1920, is an attempt by the author to present to the public, in a non-technical manner, his ideas about space flight of the future. The basic elements of astronomy, propulsion, and navigation are cleverly interwoven into a simple plot.

Circa 2017, six fabulously wealthy men—Laplace, a Frenchman; Newton, an Englishman; Helmholtz, a German; Franklin, an American; Galileo, an Italian; and Inanov, a Russian—are working jointly in their extensively equipped and well staffed laboratories located in the Himalaya mountains. The first few chapters are a running description of the design, construction, and first manned flight of a satellite around the earth. Later follows a trip to the moon and, finally, a trip along a solar orbit in a larger and more sophisticated machine.

Since the book was published some 40 years ago, it should be judged in proper perspective. Some of the author's notions about the powerplant, fuel, and propulsion could be questioned now, but, by and large, the methods of attacking numerous difficult problems connected with space flight, such as sustaining human life aboard the vehicle, were basically the same then as they are now.

A few cases of breezy terminology, such as "aerodynamic pipe" and "blast," being verbatim translations, are refreshingly closer to actuality than the accepted "wind tunnel" and "thrust."

Perhaps the main value of the book is getting to know the author himself—a modest, unassuming teacher of mathematics and physics who had but one desire in life: To unchain mankind from the earth. This man, born half a century ahead of his time, worked all his life to overcome the indifference, inertia, and ignorance of his contemporaries.

In addition to his scientific achievements, K. E. Tsiolkovskii was a thinker and a philosopher. Between 1891 and 1930, there were some 80 published papers and 50 unpublished manuscripts accredited to him. The list which follows gives but a few of the titles, indicating that he was also deeply concerned with ethic, moral, and even religious problems of society:

Natural Bases of Morality; Knowledge and its Propagation; The Genius and his Sorrows; Monism of the Universe; Universal Alphabet, Grammar, and Language; Love of Self and True Selfishness; Social Organizations of Humanity; Ethics and Science; The Prime Cause; Thought; Social Foundation; Imagination; Thinker from Galilee; Theorems of Life, Explanation of Monism and Ethics; and What to do upon the Earth?

This book, Tsiolkovskii's only novel, will make an interesting addition to anyone's library, or an inspiring gift to a young, budding astronaut.

—A. N. Petroff
Cessna Aircraft Co.

RECEIVED

Synthesis of New High Temperature Materials by J. L. Engelke and others (Stanford Research Institute, for WADD, USAF, Order PB 161720 from OTS, U.S, Dept. of Commerce, Washington 25, D.C.. 44 pp., $1.25).

Starbound by Eileen and Raymond Schussler (G. P. Putnam's Sons, New York, N.Y., 160 pp., $2.95). For children.

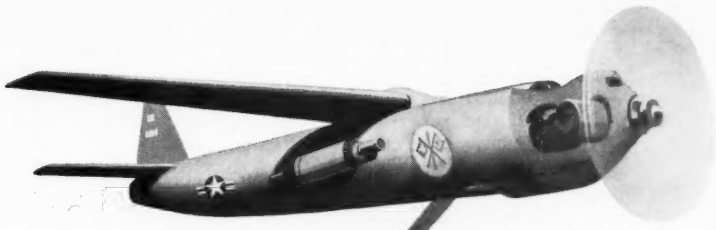
Basics of Gyroscopes by Carl Machove., Vols. 1 & 2 (John F. Rider Publisher, Iner, New York, N.Y., 114 pp., $3.30 each).

Aerospace Dictionary by Frank Gaynor (Philosophical Library, New York, N.Y., 260 pp., $6.00).

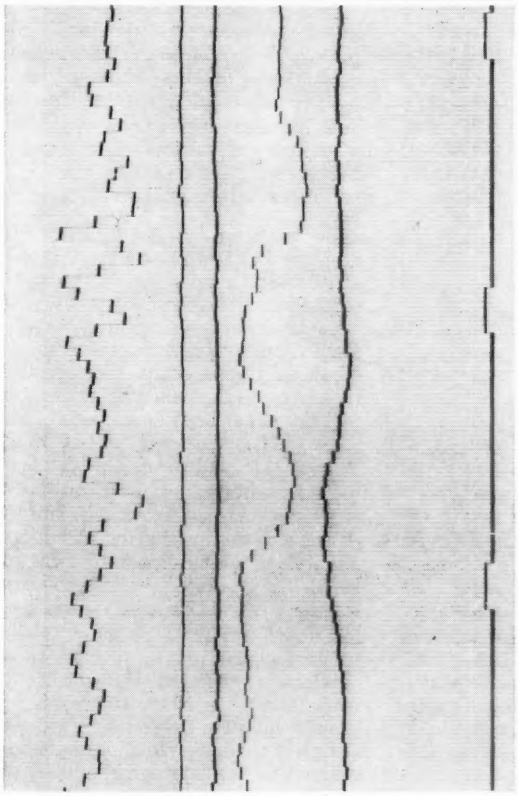
Dictionary of Automatic Control by Robert J. Bibbero (Reinhold Publishing Corp., 269 pp., $6.00).

The Universe at Large by Hermann Bondi (Pocketbook edition, Anchor Books, Doubleday & Co., Garden City, N.Y., 154 pp., $0.95).

Survey of Research Projects in the Field of Aviation Safety, 1960 Annual Supplement (The Daniel & Florence Guggenheim Aviation Safety Center, Cornell Univ., 468 Park Ave. So., New York, N.Y., 28 pp.). ◆◆



Tracking a Surveillance Drone with the Visicorder



Record shown ¼ actual size.

Drone surveillance and reconnaissance gives U.S. Army combat units a high-altitude vantage point with much broader horizons from which to view battlefield action and terrain.

If effective use of the data gathered by the drone—the "eye in the sky"—is to be made, accurate instruments have to be on hand to monitor the drone's position and movement, its operational behavior and its response to flight commands. Telemetry supplies the radio link which transmits all this behavior information to a thoroughly-instrumented mobile tactical command post developed by Tele-Dynamics Division of American Bosch Arma Corp.

The Honeywell Model 1012 Visicorder has been selected as the direct readout unit in the Tele-Dynamics Drone Surveillance Telemetry system. In use with its companion instrumentation, the 36-channel Visicorder simultaneously displays the 22 channels of information required to track a drone, plus the timing traces.

In the Tele-Dynamics van, which serves as a tactical command post, the Visicorder provides both an instant "quick look" and a permanent record of the drone's operational parameters.

Signals are transmitted over a single channel by time-multiplexing. Signal and battery strength, engine speed and temperature, pitch and roll commands, altitude, airspeed, attitude (pitch and roll), yaw, acceleration (horizontal and vertical), and angle of attack are recorded by the Visicorder, along with three separate records of vibration.

Like the other units of the Tele-Dynamics system, these Honeywell Visicorders are built for rugged service . . . to deliver the data . . . when the drone is up and the chips are down.

Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration of how a Visicorder Oscillograph will save you time and money in data acquisition. OEM inquiries invited.

Reference Data: write for bulletins 906, 1012, 1108 and 1406.

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(CONTINUED FROM PAGE 37)

of pore spacings and size distributions of currently available porous tungsten samples, as well as methods and problems of measurement of the neutral fraction. Husmann also reported on transport measurements of both inert gases and cesium through porous emitters and attempted to interpret his measurements in terms of ionization efficiencies. This interpretation may be questioned in terms of the resultant absolute values of ionization efficiency obtained, but showed qualitatively the expected decrease in efficiency with both increasing temperature and coarseness of the porous samples, as well as indicating the possibility of changes in porosity with time due to continuous sintering at operating temperatures.

Gas-Discharge Sources

This general type of source has the advantage over surface ionization sources in that any material which can be vaporized at a reasonable temperature may be used as an expellant. All of the gas discharge sources used for propulsion appear to be of a type which may be categorized as trapped electron sources. In the Penning (or PIG) type of source using a cold cathode, or the Finkelstein ion source using a thermionic cathode, the electrons are trapped in an axial magnetic field between the cathode and another point on the axis at the cathode potential. In the duoplasmatron of von Ardenne the electrons are in addition funneled into a very small diameter region and reflected by a strongly convergent magnetic field. The latter source has the advantage of being able to yield extremely high current densities.

Although several laboratories in the country are working on the duoplasmatron as an ion source for propulsion, only one paper on this type of source appeared on the program. B. S. Burton Jr., of Convair, presented results of experiments with Argon. He measured 60 milliamps of A^+ ions at 5 kv, corresponding to 10^{-3} lb of thrust at a specific impulse of 16,000 sec, with a power efficiency of 52 per cent. As a propulsion unit this specific impulse is much higher than desired for early missions for electric propulsion, but the main questions which must be raised concern the validity of the measurements. The current quoted is approximately a factor of 10 higher than space-charge limitations permit to be ejected from a single aperture source into a collimated beam, without accel-decel. Burton presented reasons why ordinary space-charge limitations (as expressed in the perveance concept) may not apply to this source; but von Ardenne never reported abnormal perveances and S. Nablo, of Goodrich-High Voltage Astronautics, verified from the floor that in his work the obtainable currents in a collimated beam are always obtained from a plasma sheath which lies at or in back of the anode surface, denying Burton's reason for excessive currents.

The currents were measured calorimetrically, eliminating secondary electrons as a source of error, but it is still necessary to be concerned about the possibility of multiple charged ions or of power which reaches the collector by means other than direct high energy ion bombardment. A verification by thrust measurement would be desirable for this ion source.

H. R. Kaufman and P. D. Reader, of NASA's Lewis Research Center, presented an interesting arc source for propulsion. This source is a modification of the Finkelstein ion source which recognizes the necessity of a gridded acceleration system for the handling of currents adequate for a propulsion device. The appropriate magnetic field is a compromise between high fields to improve efficiency of ionization and low fields which permit the discharge to establish a uniform ion density. The optimum magnetic field is 100 gauss or less, which can be obtained with only modest power losses.

An accel-decel system is used in the experiments although a decelerate electrode is avoided by means of a grounded neutralization filament. This establishes the entire beam region to within some small distance from the accelerating electrode at ground potential.

Some results of Kaufman and Reader are tabulated as follows:

V_I (volts)	2000	3000
Ion beam (amps)	0.100	0.130
Thrust (lb) assuming Hg^+	0.0021	0.0033
I_{sp} (sec) from vel. of Hg^+	4500	5500
Power efficiency (per cent)	52	69
Propellant utilization (per cent)	63	82

The propellant utilization numbers based on propellant flow rates measured over short duration runs must necessarily be rough measurements.

A major problem with this source is the short filament lifetime, of the order of two hours. It is also to be anticipated that much greater difficulties may be encountered in maintaining very long accelerating-electrode life than for the cesium ion motors because of the sensitivity of focusing-to-discharge conditions and because of a greater vapor density in the accelerating gap, which increases the likelihood of charge exchange in that region.

In another axial magnetic field arc source, shown in the two top illustrations on page 36, R. G. Meyerand Jr., of United Aircraft, uses no ion acceleration other than that which exists within the plasma. For reasons which are not understood, the potential distribution within the plasma assumes the shape shown in the bottom drawing on that page, so that only ions formed in the immediate vicinity of the cathode strike it, the others being accelerated toward the exit aperture and a grounded target at a distance which has been as large as $3^1/_2$ to 4 ft away.

Since the exhaust is part of the neutral plasma of the discharge, there is no neutralization problem. However, the question remains as to what happens to the discharge as the collecting electrode is moved to infinity.

The source has operated with beam currents of 5 amps and measured thrusts of several millipounds for periods of several hours, and up to 10 millipounds with lifetimes of a few minutes. Power efficiencies of 25 per cent have been obtained but the cathode power and solenoid power were neglected in computing this efficiency. The justification for this neglect is not clear.

It should be noted that this type of motor is inherently a lower specific impulse device than either the cesium ion motor or other arc source motors. If it is successful it may bridge the gap between thermal arc jets and other types of ion motors.

Measurement Techniques

Advances in ion propulsion, as in other fields, must be based on dependable measurements. In certain cases serious doubts about the validity of results may be raised because of questions about the nature of the measurements, but for the most part a thorough and unambiguous set of techniques has been developed.

L. R. Gallagher, *et al.*, of EOS, showed that with proper precautions beam current, beam power, and thrust measurements all agree. Collectors must be deeply corrugated and properly biased with respect to grids to avoid large effects from secondary electrons. The thrust-balance collector, shown on page 37, is an especially useful tool that should receive wider application, especially in connection with arc sources where there may be serious question as to the specific charge of the ions. In addition to advantages of rapidity and simplicity of

operation and the involvement of the e/m value, absolute force measurements have an advantage over other measurements that the most probable source of error, stray fields, yields a reduced value, whereas errors in current and beam power measurements usually yield values larger than the true beam current.

An interesting collector used by Sellen and Shelton was a flat plate with a radial set of holes backed up by small Faraday cups which made possible an examination of the beam profile. Through mechanical or electrical scanning they could display the beam profile on an oscilloscope. This profile provides an important means for interpretation of performance.

Etter, *et al.*, used a collector made of a series of flat rings separated by cylinders. By the application of the proper voltage between the rings and the cylinders they were able to separate electron and ion currents. This provided a tool for examining beam profiles when the ion beam was neutralized.

L. V. Baldwin and V. A. Sandborn, of Lewis Research Center, described a hot-wire calorimeter for the examination of beam profiles. In this device the temperature-sensitive resistance of a very fine wire is measured as the wire moves across the beam. By moving a linear array of such calorimeters through the beam, Baldwin was able to rapidly determine the two-dimensional beam profile.

An electron beam probe used by Sellen and Shelton is also an interesting tool for beam analysis. The deflection of an electron beam by an ion beam, as indicated by the position of a spot on a fluorescent screen, could be used as a measure of fields in the ion beam. A similar device using electrical, instead of visual, readout was described by Gallagher but the latter instrument had not been used with ion beams by meeting time.

The use of Langmuir probes for the determination of space potentials, electron densities, and electron temperatures appears not to have been attempted with conventional ion motors because of the difficulties in interpretation imposed by the directed beam; but Meyerand, whose entire accelerating region is part of the positive column of a discharge, used such probes and succeeded in obtaining consistent measurements of the space potential.

D. Moore and P. Kinzie, of Convair, used an emitting probe to determine space potential. In this type of probe the potential is determined by the onset of thermionic emission from a heated probe. However, Shelton questioned whether this measured anything but the potential which permitted electrons to flow continuously to the beam boundaries. Meyerand measured electron densities using a microwave probe. This tool might also be used with more conventional ion propulsion development programs but the lower charge density usually involved makes such probing less convenient.

Diagnostic Experiments

A particularly elegant and carefully done set of diagnostic experiments was described by Sellen and Shelton. A distinction is made here between measurements carried out in order to ascertain or verify motor performance parameters and those experiments which were performed with the aim of improving our understanding of ion beam phenomena.

One of their experiments pertained to the turn-around and spreading of unneutralized ion beams. Using a planar gridded source of large aspect ratio, operating with an ion acceleration of 40 volts, they observed turn-around when the grid to collector spacing was 20 times the grid to ionizer distance. The calculated ratio of these distances for turn-around should have been 3 on the basis of an unneutralized ion beam. It has been presumed that, even though the ion energy is only 40 ev, enough electrons are introduced into the beam to produce partial neutralization.

To produce space-charge effects at higher voltage and to eliminate the discrepancy between the calculated and observed turn-around distances quoted above, Sellen and Shelton also performed some pulsed beam experiments. In these a voltage which permits ions to flow from the ionizer was very rapidly applied and the effects which occurred during the approach to equilibrium were observed. For times small compared to a millisecond following the application of voltage, the collector currents were of the correct value for a virtual anode very close to the accelerating grid, in agreement with predictions for unneutralized beams. This current rose to a much larger value in approximately 1 millisec as the trapped electron density built up to provide essentially complete neutrality. Detailed studies covered variation of current density over the collector surface with time, voltage, interelectrode spacing, and grid-to-collector spacing and are too extensive to review here in detail. It is, however, especially interesting to note that the time for build-up to neutrality was found to be independent of distance to the collector for grid-collector spacings greater than 5 cm.

Sellen and Shelton also reported on an elaborate series of experiments designed to study the source of observed oscillations whose period was approximately equal to the transit time over a wide range of voltage and grid-collector spacing. These experiments included a spectroscopic examination of the emitted light, an examination of ion energies with a 127 deg electrostatic analyzer, and observation of fields in the beam with an electron probe. They arrived at a rather tentative explanation of the transit time oscillations based on the manner in which space charge might be expected to build up and collapse following a slight increase in ion stream injection. However, until a satisfactory plasma wave propagation treatment is incorporated into the theory of the oscillations, it must be regarded as speculative.

Occasionally these transit time oscillations occurred in periodic bursts. It was suggested that the oscillations could build up in amplitude until the electron trap is destroyed with the subsequent reduction in beam current. The build-up would then follow the pattern observed for the tran-

Shake-Down Chamber For Astronauts

This environmental test chamber, nearing completion at Boeing Aircraft Co., can subject an astronaut to simultaneous stresses of noise, intense light, vibration, pressure, temperature, and atmospheric contamination. The subject under test performs such tasks as identify targets on a radar screen and adjust dials on a screen. A joint project of the Boeing Aerospace Div.'s environmental-control, aviation-medicine, and human-engineering groups, the test chamber can be used for studies of underground launch control and submarine operations as well as space, flight.

sient behavior of the pulsed ion beam until the onset of transit time oscillations again.

No evidence for oscillations at the electron plasma frequency could be found.

Neutralization

The questions as to whether an ion beam in space can be neutralized, how it might become neutralized, the various ways of injecting electrons to achieve neutralization, and the various analytic approaches to solutions of these problems have been and continue to be the major area of controversy in electrostatic propulsion.

In the laboratory, beams neutralize very readily, even beams of total perveances which are large enough to cause beam turn-around. This appears to be true at all laboratories where sufficient beam currents have been obtained, at the Ramo-Wooldridge Laboratories, Electro-Optical Systems, Inc., and at NASA's Lewis Laboratories. This neutralization, furthermore, appears to be independent of whether or not a conscious effort is made to achieve such neutralization. Only the very careful observations made at very low voltages and on transient effects by Sellen and Shelton demonstrate that there are conditions under which ion beams are unneutralized.

It has been widely, but not universally, assumed that the neutralization in space will not be so readily come by. A wide variety of approaches has been taken to study the problem. Experimentally, Etter, *et al.*, have purported to have solved the neutralization problem with an accel-decel system with electron trap used for neutralization scheme based on analog-computer calculations. The claim is that with this geometry each ion passing through the electron cloud formed in the region of electron injection takes with it an electron moving with a downstream component of velocity which exactly matches the ion, but the basis of this contention appears unclear. The experimental evidence lies in the widening of the beam when too many or too few electrons are ejected, but they do not appear to have distinguished between space-charge effects and effects on the ion optics due to changes of potential in the electron injection region. It is difficult to separate experimentally these two effects in low-perveance beams.

A very wide range of theoretical approaches to the neutralization problem was covered at the conference. R. N. Seitz, R. D. Shelton, and E. Stuhlinger have considered the effect of electrons released from planes parallel to the direction of ion travel in an infinite slab beam; and P. French, of TRW, considered electrons injected into spiral trajectories about the axis of a circular beam. Both of these treatments failed to include interactions by which electrons may get trapped in potential wells. It is not improbable that an electron ejection scheme can be devised in which electron trajectories and ion trajectories, unaffected by each other except for gross space charge effects, might produce an adequately neutralized beam. However, electron trajectories will be significantly affected by collisions or plasma inhomogeneities so that the neglect of such interactions appears to make these treatments inadequate.

G. C. Baldwin, of General Electric, presented a semi-quantitative treatment based on placing the decelerating electrode at a distance downstream large enough to get an electron trap in the region between this electrode and the accelerating electrode. Evidence of neutralization automatically achieved in vacuum chambers by various groups indicates that such a trap will indeed fill in with electrons. Baldwin then argued that the beam will automatically drag enough electrons out of this electron trap to provide a neutralized exhaust.

Baldwin appears merely to have pushed somewhat downstream the neutralization problem. But it is not clear why the neutralization is simpler beyond his trapping electrode than, for example, beyond a thermionically emitting decelerating electrode placed so close to the accelerating electrode that a trap between the two electrodes never forms.

W. D. Halverson, of Allison Div. of General Motors, and H. M. DeGroff and R. A. Holmes, of Midwest Science, presented an approach which they term electrogasdynamic, in which the electrons are treated as a perfect gas. This treatment, in effect, appears to neglect completely any ordered motion of the electrons produced by fields within the exhaust. This approximation may prove to be superior to those in which interaction terms are completely neglected, but at the present time the approach is in a preliminary state. All that can be stated is that some of the types of solutions which appear to exist may satisfy neutralization requirements.

O. von Roos and P. R. Peabody, of JPL-CIT, have undertaken a theoretical approach which may prove to be the most satisfactory. Unfortunately, involved machine computations had not been completed by the time of the meeting. They have been attempting to find the potential and electron distributions in the beam which are consistent with each other through the collisionless Boltzmann equation. In this treatment individual particle interactions are neglected, but interactions between the electrons and charge density inhomogeneities are included. W. K. R. Watson, of EOS, presented a defense of this treatment, showing that this type of interaction is a markedly more effective means of electron energy loss than the coulomb scattering process more often discussed. This approach as presently formulated involves some unrealistic boundary conditions which were considered by many to be a serious drawback. However, if the computational problems can be solved even for highly idealized boundary conditions, it appears that a major step in understanding an ion motor exhaust might be made.

Miscellaneous

There were several papers of significance to the field not easily assigned to categories.

G. S. Kino and K. J. Harker, of Stanford Univ., discussed the application of some recently evolved analytical techniques of treating space-charge flow to cases of curvilinear trajectories for ion beams. They applied these methods to deriving some trajectories and required electrode shapes. While the designs presented had the advantage that the electrodes tend to shield thermally the emitter, they tended to be designs which had serious drawbacks, such as nonuniformity of current densities over the emitter surface or lack of adaptability to iteration. However, this paper was presented more as a review of possible analytical methods, rather than as a presentation of final designs.

R. J. Sunderland, *et al.*, of Aerojet-General, described experiments directed toward the development of a negative ion source which utilizes surface ionization of molecules of relatively high electron affinity on low work function surfaces. Sulfur hexafluoride was adsorbed on the interior of a tantalum cavity coated with either barium oxide, strontium oxide, or zirconium carbide and the ion beam emerging from a hole was analyzed with a mass spectrometer. The mass ionization efficiencies observed were less than 1 per cent, but there was evidence that the oxide coatings were chemically attached or poisoned by the SF_6 in the early stages of exposure, and hence the ionization observed occurred principally on either tantalum or some surface coating of an unknown composition and high work function.

V. E. Krohn, of TRW, presented the only paper on colloid propulsion research at this meeting. Charged

metal droplets of Wood's metal and similar alloys were produced with a charge-to-mass ratio as high as 80 coulombs/kg and with radii ranging from 0.75 to 0.05 mu or smaller. Unfortunately, it was shown that large numbers of metal ions are produced along with the droplets; and, indeed, although most of the mass flow is in the form of colloids, most of the positive current produced was carried by these ions. This is discouraging for propulsion application, and so several methods were employed in an attempt to reduce the ion ratio. To date these have been without success.

Two papers were presented on sputtering, which will in all likelihood prove to be the phenomenon which will limit the useful lifetime of ion motors. E. T. Pitkin, of Astro Div., Marquardt, described results obtained for xenon, krypton, and argon ions in the energy range of 10-40 kev and for a wide range of incident angles on copper, molybdenum, and tungsten. The sputtering ratios observed were uniformly lower by approximately a factor of 3 on the refractory metals, and increased markedly as the beam angle with respect to the normal was increased.

P. K. Rol, *et al.*, of F.O.M. Lab voor Massaspectrografie, Amsterdam, presented results of carefully executed and extensive experiments with a wide variety of ions in the energy range of 5-20 kev on both mono- and polycrystalline copper. Spectacular variations in the sputtering yield as a function of incident angle on single crystalline material faces gave support to an interesting approach to a theory of sputtering which he presented. This may mark a significant advance in the understanding of the phenomena and our ability to calculate sputtering ratios.

Space Testing

If there was one topic which could be described as being most "in the air," and most frequently the topic of discussion in the lobbies and corridors, it was the space testing of ion motors. The conference summary by Stuhlinger, the final two papers of the conference, and the open discussion which followed were all concerned with this subject. It was generally agreed that the motivation for the earliest possible flight test was an experimental check on the feasibility of obtaining thrust, namely, a neutralization test, under the realistic boundary conditions of space.

D. G. Elliott, of JPL-CIT, presented the results of an analysis of some of the problems of conducting such a space test considered from the standpoint of power supplies, attainable thrusts and test durations, suitable trajectories, and thrust measurement techniques. A. W. Thompson, *et al.*, of NASA Marshall SFC, in the second paper on this topic, agreed with Elliott that batteries would probably provide the energy source for initial spaceflight tests. Elliott estimated the mass requirements for a silver oxide-zinc battery pack and appropriate inverter, suitable telemetry equipment, an ion motor, and the mechanical support structure.

Of several possible launch vehicles, the Scout was considered both by Thompson and Elliott to be preferred in providing adequate payload launching capability at minimal cost for the earliest tests. The four-stage solid propellant Scout can place a 150-lb payload into a 300-n. mi. circular orbit, or it can be used for approximately vertical ascent high-altitude probes. Thompson pointed out that a major advantage of the vertical probe trajectory arises in connection with telemetry and data-gathering considerations. A satellite in a 300-mile orbit is within line of sight from a single receiving station for only approximately 9 min on each pass. Thus a comprehensive test program on a satellite would require either coordinated multiple stations or a high data rate storage capability recorder within the satellite. For the ballistic shot, however, it is possible to receive most of the telemetry transmission at a single ground station. In order to give the redundancy that is desirable for insuring acquistion of all data, it is also possible to have 3 or 4 ground stations receiving the single transmission on a vertical trajectory shot. He also pointed out that the probability of success for a probe shot is statistically much better than that for a satellite.

Elliott calculated the payload mass versus time available above 250 n. mi. for both the vertical trajectory and the 300-mile satellite orbit. The intersections of these curves with the dashed curves yield the available test durations for the two types of trajectory and for the three thrust levels considered which a Scout could provide. For example, a 10 millipound thrust motor could be tested for 1.5 hr in a satellite orbit or for 1.4 hr in a ballistic probe shot. Both of these times would appear greater than the minimum necessary. Thompson estimated that the cost of a single Scout shot plus packaging, environmental testing, etc. would be approximately $2,500,000. He also pointed out the necessity of considering the influence of the particle and plasma environment near the earth in which the test shot will be performed. He emphasized the necessity of redundancy in the instrumentation required to provide a clear answer as to whether or not the ion motor performed, and if not to what extent it failed.

Elliott described several methods of making thrust measurements in flight, principally those which involved changes in the vehicle's motion. These included: (1) linear acceleration of the vehicle center of mass, which would require attitude stabiliza-

"Little Poison"

The Army's new M-55 weapon system, developed by Arthur D. Little, Inc., lets fly with one of its 45 solid-propellant barrage rockets in a field demonstration. Rounds measure 6 ft 4 in. long and approximately $4^1/_2$ in. in diam, deliver PD chemical-agent warhead. Salvo firing can blanket a wide area with agent. Launch tubes are fiber glass. Norris Thermador produces some components.

tion, and (2) angular acceleration about one of the principal inertial axes of the vehicle. Thrust programs of the first type could result in changes either in orbit altitude or eccentricity, or in motion relative to a reference object released from the vehicle.

However, the conclusion was drawn that the angular acceleration technique would produce a more readily observable motion change. The spin dynamics of a test package under the application of tangential thrust from an ion motor were examined in detail, together with the effect of extraneous torques due to the earth's magnetic field and to nonrigidity of the vehicle.

As an example of such a test, Elliott described a Scout payload package weighing 119 lb and employing a 10 millipound ion motor mounted to provide a thrust moment about principal spin axis. Starting from given initial conditions such a motor would within the first 57 min of a ballistic test reduce the spin rate from 160 rpm to 0, while the precession rate would change from 31 to 1.1 rpm about a precession angle which starts at 2 deg and changes rapidly in the last 10 min of this period to 90 deg.

In the discussion that followed considerable attention was given to the question raised by Stuhlinger as to whether or not a thrust measurement was actually necessary on the initial test. It was pointed out from the floor that demonstration of the absence of an electric field at the outermost electrode would be sufficient, but that such measurements are difficult and subject to ambiguities when attempted in the space environment. Similarly, it was pointed out in a discussion between R. S. H. Toms, of EOS, and Stuhlinger that a measurement of a force between the ion motor and the rest of the package could also be ambiguous, in that turn-around ions and field lines could terminate on parts of the structure other than the motor, and thus one could have "push without thrust." Another topic of discussion was the desirability of including checks for oscillations in the exhaust among the electrical measurements, if such could be made without excessive requirement on the telemetry system.

In general, however, it was the consensus that both electrical and dynamical (thrust) measurements were desirable for reasons of redundancy. It was further noted by J. Paulson, of JPL-CIT, that thrust measurements were probably essential to provide unambiguous justification for future, large-scale development programs.

Conclusions

From the material presented at this conference certain general conclusions may be drawn as follows:

1. No unexpected problems appear to have arisen in cesium ion motor development. Laboratory motors have yielded desired current densities at the ionizer temperatures which had been anticipated. Electrode interception has been low enough to be encouraging. It is unfortunate that neutral efflux measurements have not been made with sufficient precision to ascertain whether the high ionization efficiencies that have been calculated are in practice achieved. This parameter needs to be carefully measured, and cesium ion motors should be pushed rapidly to higher levels of thrust. More attention should be devoted to reducing extraneous radiation in order to make demonstration engines with measured efficiencies close to the theoretically calculable values.

2. Results presented on gaseous-discharge sources are very encouraging. Further and more widespread efforts should be undertaken on such devices in order to improve the understanding of their operation, eliminate ambiguities in the measurement of performance parameters, improve efficiencies and lifetimes, and investigate a wider range of configurations.

3. Although beam neutralization is easily accomplished in the laboratory, it is not completely clear that neutralization in space will occur so readily. In his concluding remarks Ernst Stuhlinger suggested that a vacuum chamber test be made in which neutralization is initally prevented by a thorough exclusion of all electrons until the neutralizer is turned on, so that it is possible to go from an unneutralized to a neutralized condition through controlled electron injection. He then suggested that the electron injection configuration which passes this test be the one which should be tested in space. However, the ease with which neutralization occurs in laboratory devices suggests that, for any small bounded region, the neutralization will be accomplished as soon as electrons are released in adequate numbers with any reasonable method of injection. It may be that the most convincing earthbound neutralization demonstrations will be those accomplished with digital computers rather than vacuum tanks.

4. Accordingly, it is essential that space-flight tests be made as soon as possible. It is not necessary, however, that initial space tests be made on a very large scale. Even one to 10 millipound cesium ion engines require large enough perveances that thorough beam neutralization is essential for their performance. Because of the importance of such tests for the future of the ion motor program, it is essential that initial experiments be well planned and executed in order to provide unambiguous answers to the basic questions and to distinguish clearly between failures for fundamental reasons and those which result from mechanical malfunctions. ♦♦

U. S. Ion Propulsion Program

(CONTINUED FROM PAGE 33)

nation of orbital eccentricity, and the changing of the plane of the orbit in those cases where the satellite carries already an electric power supply of considerable power which can be made available for the electric vernier control. An arc-jet system will be preferable if the power level is moderate. If power in excess of about 30 kw is available, and if the total required velocity change of the vehicle, accumulated during the total time of operation, is greater than 100 to 200 m sec^{-1}, an ion system will be superior to arc-jet or chemical systems as far as the weight of the system is concerned. One particular advantage of ion systems as vernier controls would be the very fine and precise metering of thrust which they provide.

Ionic-propulsion systems may also be used to transport large satellite payloads between orbits. The ion rocket becomes superior to high acceleration propulsion systems, such as chemical and nuclear rockets, only when long flight-times are permissible, and when a large electric power supply is required anyway (for radar picket satellites, radio-jamming transmitters, etc.).

The table, right, shows a typical set of parameters for the transfer from a 300-mile orbit to a 22,000-mile orbit of an electrostatically propelled radar early-warning satellite using an augmented 60-kw Snap VIII power

Parameter	Value
Satellite weight	10,000 lb
Payload weight (including powerplant)	9000 lb
Powerplant weight	3000 lb
Propellant weight	1000 lb
One-way flight-time	4 mos
Assumed power-to-weight ratio of powerplant	0.044 kw/kg
Assumed power conversion efficiency of thrust device	80%
Electric-power requirement	60 kw
Initial orbit	300 miles
Final orbit	22,000 miles

supply. Such a transportation system could readily be in operation before the end of this decade.

Another prominent application for these propulsion systems would be that of a "space tugboat" which would repeatedly haul cargo from a low orbit around the Earth to a higher Earth orbit or to a low orbit around the moon. Stuhlinger has carried out a mission study of this concept (see Reference 1). The results of this study are shown in the following table.

Parameter	Value
Payload mass	100 tons
Propellant mass	19 tons
Initial mass	136 tons
Vehicle mass	17 tons
Round-trip flight-time	2 mos
Assumed power-to-weight ratio of power supply	0.3 kw/kg
Specific impulse	8000 lb-sec/lb
Electrical-power input	5.7 megawatts

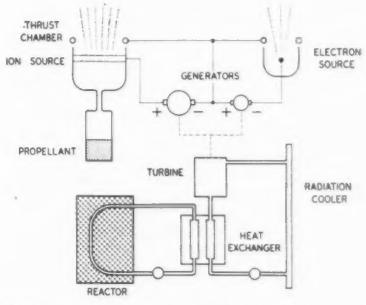
An artist's sketch of a lunar ferry is shown in the photo on page 33. The thimble-shaped device at the bottom end of the long tube is the reactor with its shadow shield. The two cylindrical bodies at the upper end of the tube are the turbine and the generator. The large disc-shaped plate near the upper end of the tube is the radiator, and the plunger-shaped member at the left end of the boom represents the ion-rocket motor. On the right side of the boom is a hydrogen-oxygen rocket to land the payload on the surface of the moon. This rocket is shown in greater detail in the inset. Two shields are shown on either side of the lunar-landing rocket to shield the cryogenic propellants from the radiator and from the sun.

As shown in the table above, the principal advantage to an ionically propelled "tugboat" would reside in the small mass of propellant required to carry out a round-trip mission once the initial tug rocket had been placed into orbit.

An additional major application for ion rockets is that of interplanetary propulsion to Mars and Venus. Many authors have treated the question of one-way and round-trip missions to Mars and have shown that ion rockets become competitive with chemical and nuclear rockets even for manned minimum-time voyages. Wolfgang Moeckel at NASA's Lewis Research Center has shown that, making reasonable assumptions (equal mass ratios, 0.45 kw/kg for the ion-rocket power supply), an ionic-propulsion system may be programmed in such a manner that it can make a round trip in about 600 days as opposed to about 800 days for a comparable nuclear rocket (Reference 3). This includes waiting time at Mars, as well as the rendezvous time with the Earth on the return trip. Of course, the final word cannot yet be said regarding the relative merits of various advanced propulsion systems since great improvements in the technology may occur between now and the time when these systems are ready for use (probably about 1975).

Finally, electrical propulsion systems become the most promising means of propulsion for space probes and space exploration much beyond the orbit of Mars. For visits to the outer planets and research probes to the vicinity of the sun and out of the planes of the planetary orbits, ion rockets provide faster transit and greater payload capability than nuclear or chemical rockets can possibly afford. Fox (Reference 2) has shown that the round-trip travel time for an ion-rocket probe to Jupiter could be as low as three years.

To summarize, ionic-propulsion systems appear to be primarily useful for unmanned probes into deep space and for manned vehicles to the nearer planets. They may find application for satellite vernier control and satellite transfer, provided that the satellite carries a large electric power supply, anyway, which will be needed for other purposes after control or transfer has been accomplished. Ferry vehicles to the moon may well be equipped with ion-propulsion systems Because of their low accelerations and long dwell times in the Van Allen belts, electrically propelled vehicles are probably unsuitable for manned flight in the neighborhood of the Earth. Beyond the orbit of the moon, ion rockets become competitive with nuclear and chemical rockets for both passenger and cargo transfer, even with conservative projections of present technology to the 1975 era. In this connection, it should be observed that electrical propulsion technology is open-ended; that is, there are no fundamental barriers to great improvements in this area. The following table shows the parameters for a possible satellite ionic-propulsion system in 1975. Such a satellite might need a large power supply for the orbital assembly of other space vehicles; that is, it would be a "construction satellite," containing electrical welding equipment, life-support equipment, etc. This example is designed more to show what effect improved power supplies can have upon flight parameters than to predict what will happen 15 years in the future.



Schematic of ion engine and power supply.

Satellite weight	200,000 lb
Payload weight (including power supply)	180,000 lb
Powerplant weight	30,000 lb
Propellant weight	20,000 lb
Specific impulse	5000 lb-sec/lb
Interorbital flight-time	2 wk
Electric-power requirement	10,000 kw
Powerplant power-to-weight ratio	0.6 kw/kg
Power-conversion efficiency	90%
Initial orbit	300 miles
Final orbit	22,000 miles

Ion Rocket Motor Development

Thrust devices for ion rockets are presently under vigorous development in the United States. The thrust units will contain three major components. These are the ion source, the accelerator, and the ion beam neutralization system.

An ion source which is to be used in a propulsion system must satisfy certain rather exacting requirements. First, it must provide an ion current density which is sufficiently large so that the thrust device weighs a small fraction of the powerplant weight. Second, it must convert the electrical power output of the power supply into ion kinetic energy with the highest possible efficiency. Third, it must convert virtually all of the propellant into ions. Fourth, it must have a long and reliable lifetime of the order of months to years. Fifth, it should utilize ions of high atomic weight.

Not many ion sources satisfy all of these criteria. Among those that do are catalytic ion sources, duoplasmatrons, and Penning effect sources.

The catalytic ion source bases its operation upon the principle that a high work function material such as tungsten can catalytically ionize nearly one-hundred per cent of a propellant material such as cesium whose ionization potential is considerably less than the work function of the tungsten. A plot of the ionization efficiency of a hot tungsten catalyst is shown on the next page. Cesium is an excellent propellant material because it has the lowest ionization potential of any stable element. At the present time, it is quite expensive in

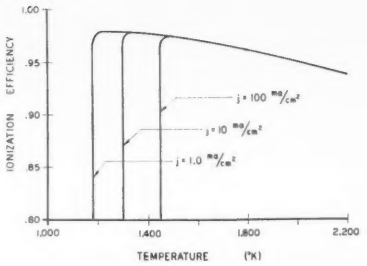
laboratory quantities. However, the existence of large deposits of concentrated cesium ore and the recent development of improved mass refinement techniques should greatly improve the prospects for cesium as a propellant.

It may be seen from the graph on this page that if the catalyst temperature drops too low, the ionization efficiency drops abruptly. This occurs when the temperature falls so low that the evaporation rate of the cesium becomes less than the rate of arrival of cesium at the ionizer. Then a layer of cesium builds up over the tungsten, the work function drops below that of cesium, and the ionization process stops. As may be seen from the illustration, if the flow rate of cesium to the catalyst is increased (leading to higher current densities drawn from the sources), there is an increase in the catalyst temperature at which the evaporation rate equals the arrival rate. Consequently, the source must be operated at a higher temperature if the ionization efficiency is to be kept high at increased flow rates.

If the ion source chances to become space-charge-limited—that is, if the ion accelerator receives more current than it can handle and chokes off part of the flow—then the difference between the arrival rate of cesium and the ion current which can be drawn off by the accelerator must evaporate as neutrals. This situation requires that the flow of propellant into the ion source be controlled very carefully. Porous emitters must be calibrated for the maximum ion current they can provide at a given accelerating voltage, and at a permissible ion-to-atom ratio, and the propellant flow must remain within these calibrated limits. No reliable and elaborate measurements of the ion/atom ratio with porous plug sources has yet been made, and the seriousness of this problem will have to be determined after this has been done. A typical current density for cesium on porous tungsten would be about 10 milliamps/cm^2.

One problem which has arisen is that of brazing porous ionizers to the cesium vapor duct. Differential thermal expansion, contamination of the porous material by diffused brazing compounds, and a requirement for extremely low leakage rates have made this a deceptively difficult problem. It appears to have been solved for small ionizers, but it may crop up again when larger motors with longer operating lives are required.

The principal source of inefficiency with catalytic ionizers is the thermal radiation loss from the hot catalyst. For a catalytic tungsten source operating at a temperature of 1500 K and a current density of 10 milliamps/cm^2,



Ionization efficiency as a functon of surface temperature for different ion current densities.

the radiation losses can amount to 20–30 per cent of the total power input to a 5000 lb-sec/lb ion rocket. Considerable effort is being devoted to methods of reducing these power losses by devising improved catalyst materials and improved heat shielding techniques.

Another promising type of source for ion rockets is the duoplasmatron. This utilizes a magnetically stabilized arc. The arc is constricted down to an hourglass shape by a magnetic field so that it can pass through a pinhole aperture in the middle of the arc column. Electrons oscillate from one end of the cylindrical arc column to the other and are prevented from escaping radially by the same axial magnetic field. Since the electron current must all pass through the pinhole aperture, the current density becomes quite high at that point and the probability of an atom passing through the pinhole without being ionized becomes correspondingly low.

These sources promise quite high power and ionization efficiency and a lifetime which is unusually long for arc sources. They are currently under development at Goodrich High Voltage Astronautics Corporation under Air Force and NASA auspices.

A third promising type of source is that developed by H. Kaufman at NASA's Lewis Research Center. This source utilizes the oscillating electron principle characteristic of magnetron oscillations at magnetic fields above anode current cutoff. The field strength needed in the Kaufman engine is of the order of 30 gauss at a potential difference of 100 volt between cathode and anode. Using mercury as a propellant, Kaufman reports an over-all power-conversion efficiency of nearly 80 per cent at a specific impulse of 5500 lb-sec/lb. The principal problems with this source at the present time appear to be low current densities and untested ion-optical characteristics. The lifetime is also unmeasured.

Once the ions have been created, they must be accelerated. Here again, the requirements are rather demanding. The accelerator must be capable of providing high current densities at accelerating voltages which are unusually low for ion sources. The electrode interception must be vanishingly small. Otherwise, with the large total amounts of cesium which have to be passed through the accelerator, the ion optical system will be eroded away. The beam must be sufficiently collimated so that not too much thrust is lost through beam divergence. The electric field at the ion emitter must be fairly uniform so that the entire source can be operated nearly up to the space-charge limit without any part of the source becoming fully space-charge-limited. As far as possible, the hot emitting surface should be shielded by the accelerator to minimize thermal radiation losses. Last, but not least, the accelerator should be designed in such a way that it is compatible with the ion beam neutralization system.

For a given voltage on the acceleration electrode, the current density which can be drawn from an ion source is limited by the space charge of the ions in transit. The charged ions in the space in front of the ionizer shield it from the acceleration field. One way to increase the current density is to apply a relatively large acceleration voltage to extract the ions from the source, and then to decelerate the ions to the desired exhaust velocity (accel-decel system). Another method is to decrease the distance from the source to the acceleration electrode. Both these methods, however, tend to increase the electric field at the source, and therefore the probability of interelectrode arcing. Arcing occurs even at relatively low voltage with cesium. This problem is under study at the present time at various laboratories.

The interception of ions by the electrodes can be held to a minimum by careful electrode design. Hughes Research Laboratory reports interception values of less than one ion intercepted for every 10^4 ions ejected from the gun at a current density of 2 milliamps/cm^2. Much of this interception is probably caused by charge exchange. This occurs when a fast ion transfers its charge to a drifting neutral by a quantum-mechanical transfer of an electron. Either one or both of these particles may no longer follow their proper optical trajectories, and may strike the electrodes or their supports. An experimental study is underway to measure the charge exchange cross-section of cesium.

The condition just beyond the accelerator exit aperture is also critical in determining the requirements im-

posed upon the ion optical system. For this reason, an ion beam neutralization system must be designed simultaneously with the accelerator.

This brings us to the third major problem area of ion rocket motor development: That of neutralization of the ion beam. It is necessary to eject charges of both signs at the same rate from a vehicle in space. If only charges of one sign were ejected, the vehicle would charge up until it pulled the charged particles back to the ship. Furthermore, it is necessary that the positive particles (usually positive ions) be mixed with negative particles (usually electrons) as close to the ship as possible. Otherwise, the mutual repulsion of the positive ions, if unneutralized by electrons, will cause the beam to diverge rapidly, and even to be reflected back to the ship. It should be mentioned that the electrostatic attraction which exists between the conducting ship and any unneutralized positive charge which may be present in the beam provides an energy-coupling mechanism which can transform the kinetic energy of the beam into wasted kinetic energy associated with beam divergence, beam oscillations and instabilities, and return of the beam to the vehicle. For this reason, the positive charge in the beam must be neutralized as thoroughly as possible. Thus, not only must the positive and negative currents leaving the ship be rendered equal, but in addition, the positive and negative charge densities should be as nearly equal as possible everywhere in the beam.

One obstacle which arises in trying to satisfy the above conditions is that of getting the electrons into the beam with low velocities. If the electrons are emitted from hot tungsten filaments at the edge of the beam, the electrons will be accelerated to a high velocity by the space-charge fields of the positive ions, will overshoot the center of the beam, and will oscillate back and forth across the beam. This leaves the center of the beam only partially neutralized.

It is not practical to place the electron-emitting filaments directly in the ion beam, because ion bombardment would quickly erode them away.

Several methods have been proposed for achieving fairly uniform mixing of ions and electrons when the latter are emitted along the edge of the beam. These depend in general upon the establishment of electron traps in which the electrons oscillate through the beam, and where coulomb scattering, space-charge instabilities, plasma waves, and, to some extent, inelastic scattering produce a fairly neutral plasma. The trap provides a continuous source of electrons which flow downstream with the ions and maintain beam neutrality throughout the exhaust beam. The limited experiments carried out to date suggest that this scheme may lead to a successful mechanism of space-charge neutralization. However, serious questions still remain as to whether neutralization can really be accomplished over distances of the order of kilometers. The low density of the plasma beam emerging from the neutralization system leaves open the question of instabilities which may arise. The average thermal speed of electrons emitted from an electron emitter at 1000 K is considerably greater than the ion velocity for a 3000 lb-sec/lb ion rocket. If instabilities arise, they may perturb the focusing fields of the ion accelerator and neutralization systems, destroying the electron trap and increasing electrode interception markedly. At their worst they could lead to time-dependent variations in the potential of the ship, causing the beam to switch on and off spasmodically.

Flight-Test Plans

A great number of experimental and theoretical studies were made during past years with the objective of finding a mechanism by which electrons and ions can be mixed into a plasma that is at least approximately neutral throughout the entire exhaust beam. The theoretical approaches, in order to remain manageable, must be limited in their scopes by simplifying assumptions such as one-dimensionality, no axial field within the beam, homogenous ion density across the beam, vanishing initial electron velocity, limitation to a region close to the accelerator exit, steady-state solutions, no inelastic scattering, and other similar restrictions. Even though the results of these studies are encouraging in general, the necessity of experimental proof under real space conditions has become more and more apparent during past months. A program for the development and testing of ion engine flight models is therefore being initiated at NASA. The primary objective of this program is the verification of effective beam neutralization. It is anticipated that a number of different schemes, after their thorough analysis and testing in the laboratory, will be test flown. The first flight tests will be made with short-range ballistic flights of 1 to $1^1/_2$ hours duration, reaching to altitudes of several thousand miles. The Scout vehicle apears to be a promising carrier for these tests. Later flights will be made on satellites. While the short-flights will be powered by batteries, the satellite experiments will require solar or nuclear energy to provide electric power. It is anticipated that flight testing on short ballistic flights will begin in 1962, satellite tests may be started in 1964 or 1965.

Instrumentation of these flight tests will be laid out in such a way that the functioning of the ion engine under space conditions can be completely analyzed. First, a number of current and voltage measurements will check the ion current, the neutralizer current, interception of the ion beam by electrodes and structural elements, and ion currents which are reflected back toward the spacecraft. Second, a number of probes in the exhaust beam will measure the ion density, the electron density, and the density of neutrals across the full diameter of the beam at various distances from the exit electrode. These probes will be movable so that the ion motor can also be operated with no objects extending into the flow of ions and electrons. This mode of operation is important because the ions, when impinging on probes and probe holders, will release secondary electrons which tend to falsify the original state of neutralization. Third, a number of temperature sensors will measure the temperatures of the propellant, the propellant flow control system, the ion source, the various accelerating and decelerating electrodes, the neutralizer, and other components of the ion propulsion system. Fourth, an effort will be made to measure the effect of the ion motor thrust directly. It seems that the best method for a thrust measurement is an observation of the changing vehicle spin while the thrust vector acts in a direction tangential to the spin motion. Considering the thrust forces and the moments of inertia to be expected in first short-time flight tests of ion motors, a variation in the spin rate of the payload package of 100 rpm should be obtained during an operating time of about one-half hour.

Early flight testing of neutralization schemes is of particular significance because any conceivable test facility on the ground offers only a limited volume of space-like environment, and therefore no realistic simulation of space conditions. Neutralization of an ion beam can be achieved easily in laboratory experiments, but it can be shown that the electric fields in the beam are modified by the finite tank boundaries, and that the neutralizing electrons are furnished by secondary processes which do not occur in the same fashion in empty space. Space tests are therefore mandatory in order to verify the principles of various neutralization mechanisms. Besides, space testing is also necessary to

checkout propellant feed systems and other ion engine components under weightless conditions. Based on present NASA plans, the first flights tests of ion motors should be expected in 1962. A number of tests will be flown during the following years, resulting hopefully in the design of an efficient and reliable ion motor that can be combined with a 30-kw Snap VIII nuclear-electric power supply for a long-duration flight test in 1965. The carrire vehicle for this test will probably be an Atlas-Centaur. While the primary objectives of this experiment will be the long-duration space testing of the power supply and of the ion engine, it is natural to assume that this flight will carry some scientific instruments for a first modest mission of an electric propulsion system. If launched into a satellite orbit of several hundred miles altitude, and if equipped with a control system of moderate precision, this package could slowly spiral outward through the Van Allen belts and measure radiation intensities, energies, and direction, and also the Earth's magnetic field, and, simultaneously, particles and electromagnetic radiations from the sun. Such a synoptic probing of the radiation environment of the Earth, which could be accomplished with early electric-propulsion systems in combination with Snap VIII supplies, would be of utmost value in geophysical research.

Development Projects in the U.S.

Active interest in the development and use of electrostatic propulsion systems is presently shown by the Air Force and by the National Aeronautics and Space Administration. The USAF program is handled by the Air Force Office of Scientific Research and by the Wright Air Development Division. In addition to a number of component studies and developments, one AF development project is underway with the objective of producing a complete ion engine model for extensive laboratory testing. A laboratory model of this kind could easily be the forerunner of a model suited for flight tests.

The NASA program in ion propulsion consists of three major parts: "In-house" research, contractual research and development and integration of electric-propulsion systems into the flight-mission program. The greater part of experimental and theoretical in-house research is carried out by the Lewis Research Center, one of the field centers of the Office of Advanced Research Programs under Ira H. Abbott. Responsibility for the development and flight testing of ion propulsion systems in connection with outside contractors has been vested with the Office of Launch Vehicle Programs under Maj. Gen. Don R. Ostrander, which includes the George C. Marshall Space Flight Center at Huntsville, Ala. Mission integration of electric-propulsion systems is the responsibility of the Office of Space Flight Programs under Abe Silverstein, including the subdivisions Goddard Space Flight Center and JPL.

The NASA program, too, consists presently of a number of studies and development projects of components, and the development of laboratory models. It is expected that the first models will be test flown in 1962.

The tables on pages 32–33 show a list of studies and experimental developments which are underway at industrial laboratories, universities and research institutes, and government laboratories. Just a passing glance at this list may give the impression of a somewhat incoherent over-all program. However, a deeper look at the work which is underway in our country will reveal that all these studies together represent a well-balanced and fairly complete coverage of the problem areas as they presently exist. These areas include ion sources for positive and negative ions; production and ionization of colloidal particles for ion propulsion; ion-optical designs for thrust chambers; beam neutralization schemes; propellant flow control systems; ground and flight instrumentation for complete ion engine diagnostics; sputtering and erosion; voltage breakdown phenomena; design and development of flight models; and flight-test preparation.

The present work program as represented by the list of projects in the tables aims at the solution of basic problems with which the developers of ion propulsion systems are still confronted. Once these problems are solved in principle, research and development will continue to improve performance and reliability of ion engines. It is to be expected that the electrostatic propulsion system will find useful application for elaborate deep-space probes from about 1968 on, and that it will become, in the further future, one of the favorite methods to propel large manned vehicles to the planets.

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Design Factors

(CONTINUED FROM PAGE 27)

the basic design criteria for each of the subsystems and carried out the design, procurement, fabrication, installation, and checkout of all the subsystems with the exception of the communications system. Principal subcontractors included Cubic Corp., Packard-Bell Computer, Collins Radio, Mitchell Camera Corp., Hermes Electronics, Canoga Div. of Underwood Corp., and Milgo Electronic Corp.

The complexity of the equipment for today's weapon and space systems, and the consequent requirements for highly technical field and mobile depot maintenance, have placed new demands upon the government contractors. Both maintenance and operation of the systems require greater reliance upon contractor technical personnel. The AF recognized this problem and requested Aetron and its subcontractors to furnish technical engineering representatives to advise and train AF and Civil Service personnel in the operation and maintenance of the IRSS subsystems and equipment. These services were in addition to the actual maintenance and operation of the equipment during and between launches.

The primary function of the Range Safety System is the protection of life and property on or near the launching base. This function is particularly important in combat-crew training and even more so for satellite launches, in which the polar trajectories begin over the continental U.S. The emphasis, therefore, is on the destruction of "unsafe" vehicles if necessary and on obtaining data to substantiate such action. The recording of missile performance data, which may assist in identifying the cause of component malfunction, is the primary function of the Instrumentation System.

Associated with increasing complexity of equipment and systems are increasing costs of design, materials, and manufacturing. It is therefore highly important, if development time and dollars are to be saved, that every bit of information concerning performance be extracted from the missile before the end of its one-way flight. The data-acquisition equipment at Vandenberg is capable of supplying any flight information required.

The complexes for launching the various vehicles are dispersed over the base. The launch-control centers (blockhouses) within each launch complex have direct communications with the IRSS Instrumentation Control

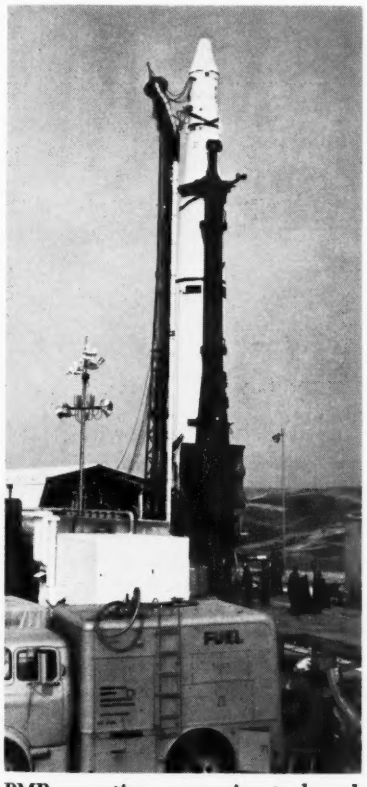
Center, but the instrumentation associated with the actual operation, countdown, and launch of a rocket (with the exception of the operation and checkout console) is not a part of the IRSS.

The Instrumentation Control Center (ICC) in the Instrumentation Squadron Headquarters Building includes the following five rooms: Range Safety Operations, COTAR and Computer, Telemetry, Timing, and Communications.

The Range Safety Operations Room, shown on page 26, is the center of IRSS activities. The equipment layout furnishes the Missile Flight Safety Officer (MFSO) with direct observation of the system's operation by means of the automatic and manual plotting boards.

For evaluating the displayed flight information, the MFSO may utilize several subsystems which provide similar data simultaneously, for example, optical and radar skyscreens, tracking radar, and COTAR. In operation, there is a period when the various tracking systems duplicate trajectory data, thereby establishing a gradual phasing out of the shorter-range skyscreens and making unnecessary an abrupt assumption of primary safety tracking functions by the longer-range radar and COTAR.

The MFSO may confirm the validity of the data being presented by the individual subsystems by reports received from the cognizant Instrumentation Squadron Officer monitoring a particular subsystem. The MFSO evaluates all data being presented, and is assisted in interpreting this data by the Missile Flight Safety Officer Assistant (MFSOA), who may monitor subsystem data of special interest, reporting to the MFSO as required. In the final evaluation, the MFSO must determine whether or not the missile is "safe" and if the trajectory is continuing within the normal flight corridor.



PMR operation—preparing to launch a Discoverer satellite.

Plotting Area Traffic

An Area Traffic Officer (ATO) is stationed at the Range Surveillance Manual Plotting Board on the extreme right side of the Range Safety Operations Room. Area traffic information, such as the movement of aircraft, railway trains, etc., is plotted on the back side of this board and viewed from the front. Countdown clocks, public address systems, and direct-line and dial-line telephone systems are available to IRSS personnel for their respective functions.

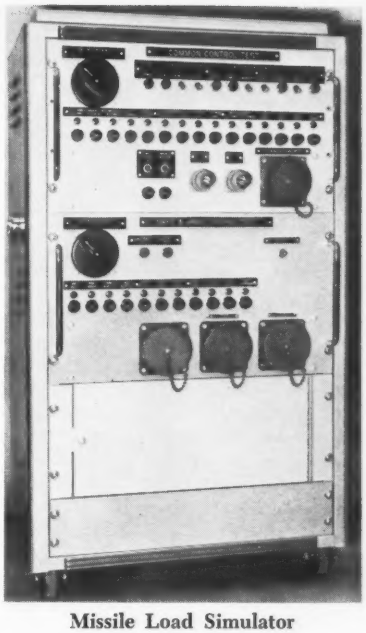
There are eight identifiable subsystems within the Range Safety System: (1) Command Destruct, (2) Control and Display, (3) Mobile Wire-Line Skyscreens, (4) Fixed and Mobile Optical Skyscreens, (5) Radar Skyscreen, (6) Radar and Data Presentation, (7) COTAR Data Acquisition, Processing, and Presentation, and (8) Communications. Other, miscellaneous equipment, such as the Operation and Checkout Console and its associated Missile Load Simulator (see page 27), are considered separately.

The Command Destruct subsystem consists of two primary and two standby transmitters. Each system, primary and standby, comprises a low-power unit and a power amplifier. The power amplifier can be activated manually or by a preset timer, which is actuated by a lift-off signal. Operation of the command-destruct circuit is by means of a switch on the console of the MFSO.

The Control and Display subsystem provides uniform visual and oral display required for standardization and rapid interpretation of information received from pertinent areas during the prelaunch, countdown, and postlaunch periods.

Wire-Line and Optical Skyscreens visually monitor the missile trajectory from lift-off to the limit of visibility; but because the wire-line skyscreens are subject to psychological errors, three of the original four wire-line skyscreens were converted to Mobile Optical Skyscreens utilizing modified gun directors.

The Radar Skyscreen subsystem has the capability of supporting launches electronically under conditions of zero optical visibility. Data is presented by a cathode-ray tube and an antiparallax overlay map engraved with trajectory and velocity destruct contours. This system is primarily for comparatively short distances after launch, but has all-weather capabilities.



Missile Load Simulator

The Radar and Data Presentation subsystem (also referred to as the Radar Tracking Facility to distinguish it from the Radar Skyscreens) continuously records and reports the flight path and space position of a launched missile.

The COTAR Data Acquisition, Processing, and Presentation subsystem (COTAR-DPS) consists of three separate but integrated subsystems: (1) AME-COTAR or Angle Measuring Equipment—Correlation Tracking and Ranging, (2) DPS or Data Processing Subsystem, and (3) associated Data Presentation equipment. The primary function of the combined COTAR-DPS passive, phase-comparison tracking system is to provide the MFSO with position information and impact prediction beginning shortly after lift-off.

The Communications subsystem, connecting the IRSS subsystems with the launch complexes and associated range-surveillance activities, features reliability, speed, and ease of operation and maintenance.

The Instrumentation System, which provides substantiating data on the reliability and performance of missiles in flight, includes Telemetry, Optical Surveillance, and Timing in its subsystems.

Telemetry facilities include both

ground and airborne systems. (Aetron participated only in the ground portion.) The ground telemetry system is employed with confidence firings to monitor the operation of the missile subsystems, to checkout the airborne telemetry system prior to flight, and to receive, demodulate, and record the telemetry signals during flight.

The ground telemetry system consists of one fixed telemetry station and two mobile checkout stations (telemetry vans). These two-axle 18,000-lb-capacity insulated trailer vans, each approximately 30 ft long, contain instrumentation identical to that of the fixed station plus additional telemetering, recording, and testing facilities and a workbench area. They are fully air-conditioned.

Primary functions of the mobile checkout stations include inspection and checkout of airborne telemetry components at the Receiving, Inspection, and Maintenance Building; checkout of the components in the missile; preflight checkout of the installed airborne telemetry system; receiving and recording flight test and trajectory data as transmitted by the airborne system; and operational and field maintenance of airborne telemetry systems and checkout of the fixed telemetry station's receiving and recording facilities.

Optical Tracking System

Seventeen camera stations, which include timing, remote-control, power, and communications facilities, comprise the Optical (Camera) Surveillance System. It utilizes high-speed (128 fps) 35-mm tracking motion picture cameras with different focal-length lenses to record in color up to 2.2 min of the external performance of the missile from shortly before launch, during lift-off, and to the limit of in-flight visibility.

The Timing System of the Instrumentation System, for operational launches, provides time references for the correlation of events and a precision time standard for the evaluation of data. The timing format is a 12-digit (binary) system. The central time-code generator provides three basic time codes and consists of an ultra-stable oscillator, pulse-rate divider, mixers, line amplifiers, and associated power supplies and control panels. Included is a receiving system for correlating precision-reference time signals from WWV.

It is an understatement to say that in the concept of a missile range there is much more than meets the eye. The design factors for a range engage a substantial portion of present technology, and what we are building is an operational base both for our defense and for our invasion of space. ♦♦

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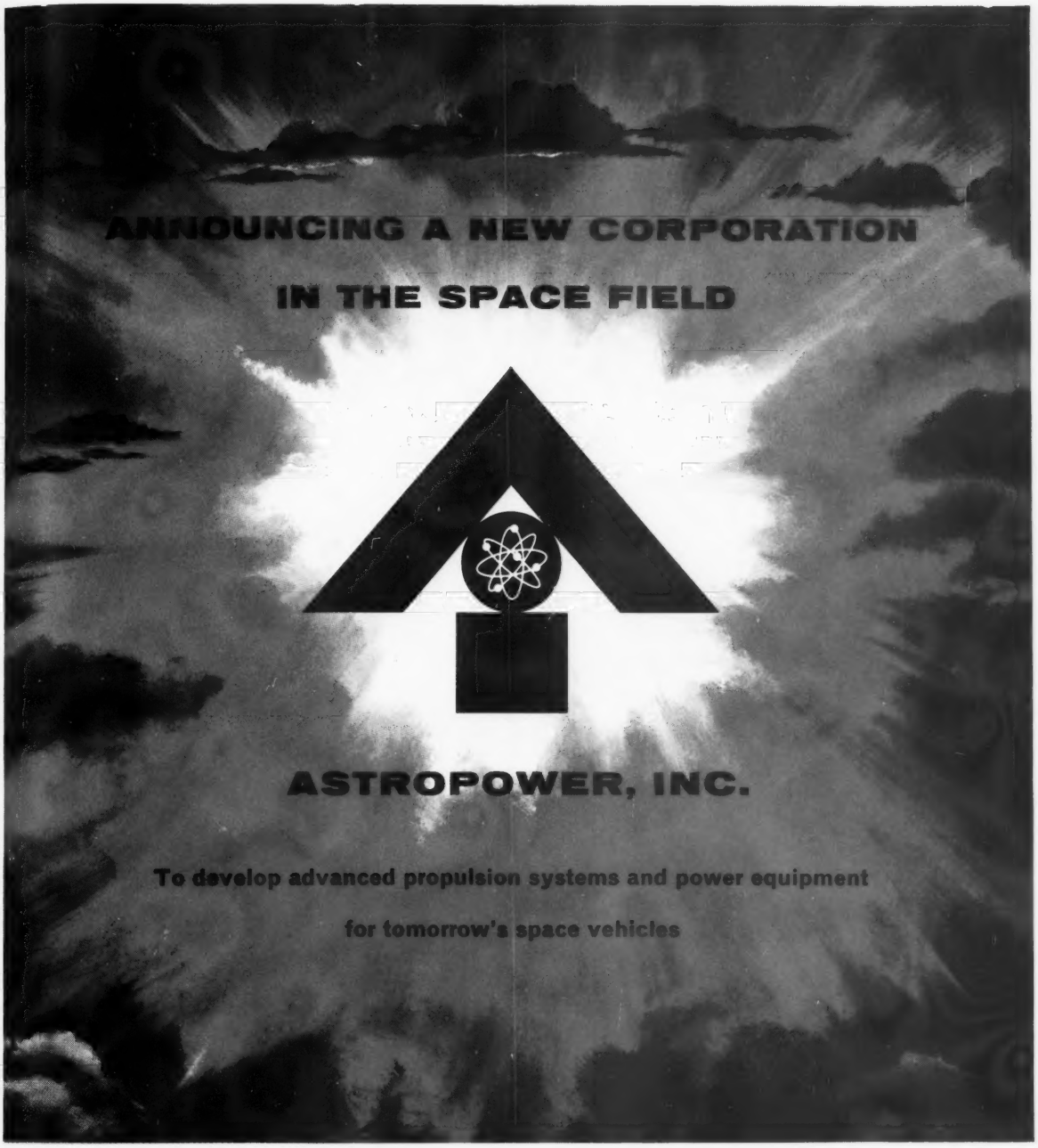
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